

**Dendroarchaeology in the Mackenzie Mountains:
The Moose Horn Pass Caribou Fence (KjRx-1)**

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Abstract

The Moose Horn Pass Caribou Fence site is a collection of three wooden fences located in the Tulita District of the Sahtu Settlement Area, of the Northwest Territories. Situated in traditional Shúhtagot'ine (Mountain Dene) territory, it is believed to have been used to assist past hunters in harvesting local game, likely caribou and/or sheep, by steering them to kill zones for harvest. The ages of the features are unknown. Territorial archaeologists recorded the site in 2009, and identified it as being suitable for dendrochronological assessment. The main fence is nearly 800 m in length, and terminates in a corral structure after descending from high ground into a valley. The two smaller fences are located north and south of the main fence, and do not descend into the valley. The project is intended to provide a build date for the fences, and to determine, if possible, how they were used and whether they were used together. In other words, were they built at the same time, or are they reflective of changing land-use?

Standard dendrochronological methods were employed to determine the fences ages. To do this, living white spruce (*Picea glauca*) trees in the area were cored to determine the overall growth pattern in the local environment. The arrangement of wide and narrow rings reflects local growing conditions. This pattern, ending at a known point in time, provides a "master" chronology, against which the archaeological wood can be compared. Cross-sections cut from the fences with their own unique patterns, referred to as "floating" chronologies, which were matched to the master chronology to determine their ages. To facilitate analysis and interpretation of fence use, near-infrared imaging using an unmanned air vehicle was employed to identify areas of high soil compaction.

At its conclusion, the research produced a dendrochronological record exceeding 1000 years, which provided the means to determine end-dates for 81 dendroarchaeological samples. The end-dates suggest that the complex was used episodically over a period of centuries.

All research was conducted in collaboration with the Government of the Northwest Territories and the Tulita Dene Band.

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Dedication

My wife, Michelle, thank you for letting me chase my dreams. I know it wasn't easy, and it certainly wasn't always without some degree of regret. It's not easy being a high school dropout, entering a classroom for the first time in almost 20 years, and it took its toll on both of us. You have always made me want to be a better man, I hope this time has done that. Throughout our years, you have been my everything, and wherever our path leads us from here, I am proud to travel it with you by my side. I love you.

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“...you have to speak for people who are no longer here to speak for themselves.”

Jack Brink – *Imagining Head-Smashed-In: Aboriginal Buffalo Hunting on the Northern Plains* (2008)

“The special magic of archaeology lies in its ability to take oddments of abandoned, long-forgotten debris and infuse these mundane objects with meaning.”

Candace Savage – *A Geography of Blood: Unearthing Memory from a Prairie Landscape* (2012)

“Dendro, if you’re not bleeding, you’re not doing it right. Actually...you probably are.”

Gary Beckhusen – 2017

Table of Contents

Permission to Use	i
Abstract	ii
Acknowledgements.....	iii
Dedication	vi
Table of Contents	ix
List of Tables.....	xiii
List of Figures	xiv
Glossary and Abbreviations	xviii
1.0 Introduction and Background.....	1
<i>1.1 Introduction.....</i>	<i>1</i>
<i>1.2 Importance of Caribou to the Shúhtagotíne.....</i>	<i>2</i>
<i>1.3 Dendrochronology</i>	<i>3</i>
<i>1.4 Principles of Dendroarchaeology</i>	<i>4</i>
<i>1.5 Dendroarchaeology in Canada.....</i>	<i>4</i>
<i>1.6 Drive Fences/Drift Lines</i>	<i>6</i>
<i>1.7 Study Area</i>	<i>6</i>
1.7.1 Geology	6
1.8.1.2 Crossdating.....	10
1.8.1.3 Program COFECHA	11
1.8.1.4 Ring Anomalies	12
1.8.1.4.1 Micro Rings.....	12
1.8.1.4.4 False Rings	17
1.8.1.4.5 Damaged Rings	17

1.8.1.4.6 Missing Rings.....	20
1.8.1.5 International Tree-Ring Data Bank	20
1.8.2 UAV Analysis	22
1.8.2.1 Type of UAV.....	22
1.8.2.2 Multispectral Analysis.....	24
1.8.3 ArcGIS Analysis	26
1.8.3.1 Elevation Modelling.....	26
<i>1.9 Research Objectives</i>	<i>28</i>
<i>1.10 Organizational Summary</i>	<i>28</i>
2.0 Title of Manuscript: Dendroarchaeology of the Moose Horn Pass Caribou Fences	30
<i>2.1 Abstract</i>	<i>30</i>
<i>2.2 Introduction.....</i>	<i>30</i>
<i>2.3 Study site</i>	<i>32</i>
<i>2.4 Methods</i>	<i>33</i>
2.4.1 Live Tree Sampling.....	33
2.4.2 Standing Dead Wood	33
2.4.3 Archaeological Samples	35
2.4.4 Laboratory Preparation Cores	37
2.4.5 Laboratory Preparation Cross-Sections.....	37
2.4.6 Sanding.....	37
2.4.7 Measurement	38
2.4.8 Crossdating Analysis.....	38
2.4.8.1 Living and Snag Samples.....	38
2.4.8.2 Archaeological Samples	38

2.4.8.3 Master Chronology.....	39
<i>2.5 Results</i>	<i>39</i>
2.5.1 Living Trees	39
2.5.2 Snags	41
2.5.3 Archaeological Wood.....	41
<i>2.6 Discussion</i>	<i>46</i>
<i>2.7 Conclusion.....</i>	<i>49</i>
<i>2.8 References</i>	<i>53</i>
3.0 Title of Manuscript: Applying UAV Obtained Multispectral Data and Dendroarchaeology to Gain Insights Regarding the Use History of the Moose Horn Pass Caribou Fence.....	56
<i>3.1 Abstract</i>	<i>56</i>
<i>3.2 Introduction.....</i>	<i>56</i>
3.2.1 Main Objective	57
<i>3.3 Study Site</i>	<i>58</i>
<i>3.4 Methods</i>	<i>61</i>
3.4.1 Dendrochronology.....	61
3.4.2 Remote Sensing.....	61
3.4.2.1 Image Preparation	61
3.4.2.2 Analysis	63
<i>3.5 Results</i>	<i>63</i>
3.5.1 Dendroarchaeological Results.....	63
3.5.2 Remote Sensing Results.....	66
<i>3.6 Discussion</i>	<i>66</i>
3.6.1 Early Use - When and How.....	69

3.6.2 Recent Use – When and How	72
3.7 Conclusion.....	78
3.8 References	79
4.0 Conclusions	81
4.1 Major findings of Chapter 2.....	81
4.2 Major findings of Chapter 3.....	81
4.3 Overall Thesis	82
4.3.1 Thesis Conclusions.....	82
4.4 Implications	84
4.5 Final Thoughts	86
5.0 References Cited	89
Appendix A: Repair	97
Appendix B: Calculations.....	112
Appendix C: Referenced Figures.....	114
Appendix D: Referenced Tables	127
Appendix E: Additional Figures	130

List of Tables

Table 2. 1 - Summary of 62 Archaeological cross-sections ages/end dates included in master chronology. Samples grouped into the feature they were obtained from, with their FYOG, End Date, and total number of rings (Years) shown. Each set were analyzed for average, median, maximum (most recent) end date, minimum (oldest) end date, and adjusted end date (average omitting maximum and minimum values). Comparisons were made between each of the groups, and between the combined plateau fences (M,N,S) and the Corral feature.	44
Table 3. 1 - End dates, sorted into groups representing a shared period of time. The groups have been further divided into sub-groups of finer temporal resolution. The main groups are denoted by the calendar in which they fall under, their code identifying when and from where they were taken, and their respective end-dates denoted as LYOG. End-date groups falling into one of the two identified date clusters are denoted with an asterisk (*).	64
Table 3. 2 - Summation of all archaeological end dates.	65
Table D. 1 - Breakdown of COFECHA flags.	128
Table D. 2 - Average ages of trees from each coring zone.	128
Table D. 3 - Key Ubiquitous Marker Years.	129

List of Figures

Figure 1. 1 - Facing north, Stelfox Mountain in the background, and a section of fence in the foreground.	7
Figure 1. 2 - The plateau and valley to the south of Stelfox Mountain, the study area where the Moose Horn Pass Caribou Fence is situated.	8
Figure 1. 3 - Micro-rings. Prud'homme, Saskatchewan white spruce (top) versus Stelfox Mountain, Northwest Territories archaeological wood (bottom).	13
Figure 1. 4 - Locally absent rings. Arrow indicates where two rings merge into one, resulting in the absence of one ring elsewhere around the stem.	14
Figure 1. 5 - Reaction (A,C,D) and compression (B) wood.	16
Figure 1. 6 - False ring, marked by white arrow. The ring appears as though it is a latewood boundary, but in fact is the result of a limiting factor causing stress to the tree at some point during the growing season.	18
Figure 1. 7 - Arrows indicating frost damaged rings within a sample. Note the cells are large, indicative of an embolism from frost shattering of cells.	19
Figure 1. 8- Absent rings indicated by a difference in total ring counts between discernable markers on either side of the affected sequence.	21
Figure 1. 9 - Stelfox Mountain, and the locations of dendrochronological studies used as comparisons against the chronology developed at Stelfox Mountain.	23
Figure 1. 10 - Screen capture of Pix4D 3D model. Arcs reflect the axis by which the model can be manipulated.	25
Figure 1. 11 - GNDVI values mapped onto research site at 2.72 cm/pixel. Red (lowest values) indicates an absence of vegetation and the darkest green (highest values) indicate healthy / thick vegetation.	25
Figure 1. 12 - Screen capture of Pix4D RGB orthomosaic. Specific details and mapping elements are added after export to mapping program like ArcMap.	27

Figure 1. 13 - ArcMap elevation model; 30cm contours (micro) and DTM of site (macro).	29
Figure 2. 1 - Coring zones indicated by red shading.	34
Figure 2. 2 - Locations of archaeological cross-sections cut from the three fences.	36
Figure 2. 3 - Graph of final Stelfox Mountain standardized master chronology, where 1.0 is average, and values +/- 1.0 represent wider and narrower rings.	40
Figure 2. 4 - Bridging effect of snag wood to overall sample size of the chronology.	42
Figure 2. 5 - Snags double the sample depth during a dramatic drop in sample size extending back to mid-18th century.	43
Figure 2. 6 - Archaeological end-date clusters plotted against the Stelfox Mountain master chronology.	45
Figure 2. 7 - Comparison of Stelfox Mountain, Mackenzie Mountains, and Kuskula Creek chronologies over their shared time periods.	47
Figure 2. 8 - Correlations between Stelfox Mountain, Mackenzie Mountains, and Kuskula Creek chronologies, 50-year segments from 1550-1999, with 19th century divergence of Stelfox Mountain chronology	48
Figure 2. 9 - Decrease in Stelfox Mountain, Mackenzie Mountains, and Kuskula Creek living tree sample size c.1750 and the increase in archaeological wood extending back in time.	50
Figure 2. 10 - Stelfox Mountain divergence from Mackenzie Mountains, and Kuskula Creek chronologies in 19th century.	51
Figure 3. 1 - Sahtu traditional trails denoted by broken lines (Sahtu Land Use Planning Board 2010. Map 5). Redstone Herd range in orange, Drum Lake calving ground in red (Wilson and Haas 2012. Fig. 4), Stelfox Mountain study area in black.	59
Figure 3. 2 - Lightly constructed portion of the minor-north fence.	60
Figure 3. 3 - UAV flight path and image capture locations over the entire study area, including the plateau and the adjoining embankment.	62

Figure 3. 4 - Major fence end-dates from western extent of major fence to corral terminus (blue line). The red triangle indicates the final cross-section requiring repair within the major fence. The green circles indicate the portion of major fence proposed to have been subject to damage and subsequent timber replacement. The black trendline demonstrates the appearance of more recent end-dates moving east from the western edge of the major fence, to the corral terminus. .67	67
Figure 3. 5 - MASL and DTM map with contours at 30cm intervals.68	68
Figure 3. 6 - DTM modelling water level shaded at 1112.1 MASL, with NIR index, 1m contours, and inset map depicting hypothesized past water flow over plateau.70	70
Figure 3. 7 - “Early use” DTM modelling water level at 1109 MASL, NIR index, and 1m contours. Includes unobserved western extent of the minor-north fence (blue dots), archaeological end-dates to 1520, and locations of cross-sections that required extensive repairs in the laboratory prior to analysis.71	71
Figure 3. 8 - Close-up of the north-fence gap, relative to potential water crossing. Note the differential NDVI returns associated with the gap area.73	73
Figure 3. 9 -“Early use” with all end-dates plotted, the proposed earliest extent of the major fence, the” pinch point” indicated by the arrow, and locations of cross-sections requiring extensive repairs in the laboratory prior to analysis. GNDVI included, with areas below 1109 MASL shaded.....74	74
Figure 3. 10 - “Recent use” with all end-dates plotted, valley river at 1072.7 MASL, lake on plateau, and GNDVI. Locations of cross-sections requiring extensive repairs in the laboratory prior to analysis, the earliest extent of the major fence, and contours at 1m intervals.76	76
Figure 3. 11“Recent use” model with the additions of snare zones, scattered timbers, and potential caribou path.77	77
Figure A. 1 - Repaired cross-sections in master chronology. Total quantity, and as a percentage of total combined archaeological and snag sample size.100	100
Figure A. 2 - 16LD011; 1232-1426101	101
Figure A. 3 - 16LD028; 1588 END DATE102	102
Figure A. 4 - 16LD029; 1642 END DATE103	103

Figure A. 5 - 16LD035; 1609-1723	104
Figure A. 6 - 16LD040; 1257-1637	105
Figure A. 7 - 16LD041; 1137-1447	106
Figure A. 8 - 16LD042; 1544-1715	107
Figure A. 9 - 16LD043; 1591 END DATE	108
Figure A. 10 - 16LD060; 1209-1437	109
Figure A. 11 - 16LD062; 1502-1610	110
Figure A. 12 - 16LD064; 1584 END DATE	111
Figure C. 1 - Photograph of Phantom IV UAV and Parrot Sequoia multi-spectral sensor array.	115
Figure C. 2 - Photograph of UAV and operator in the field.....	116
Figure C. 3 - Photograph of 5.1mm increment borer.	117
Figure C. 4 - Cores mounted on boards.	118
Figure C. 5 - Velmex Stage System.	118
Figure C. 6 - Fence line, overlapping timbers.....	119
Figure C. 7 - NDVI visual.....	120
Figure C. 8 - NIR visual.	121
Figure C. 9 - GNDVI visual.	122
Figure C. 10 - RGB and Modified RGB.	123
Figure C. 11 - Valley slope vegetation (Salix sp.).	124
Figure C. 12 - Decrease in Tree age/sample size increase from past to current.	125
Figure C. 13 - Areas suggested to have high archaeological potential.	126

Glossary and Abbreviations

Adj. Avg. –	Adjusted Average: Average that removes both the highest and lowest values from the calculation.
Archaeology –	Study of past human culture using their material remains.
Archaeological Feature –	A non-portable component of past human material culture.
Artifact –	A portable component of past human material culture.
C.E. –	Common Era, used in place of A.D. to denote calendar years.
COFECHA –	The name of a statistical analysis software program designed specifically for dendrochronological applications.
Core –	Sample taken using an increment borer. Allows for the ring pattern to be seen, while leaving the stem intact. Not destructive.
CPP –	Cultural Places Program, Government of the Northwest Territories
Cross-section –	A portion of wood cut from a tree or timber in order to obtain its ring measurements. Destructive.
Crossdate –	Pattern matching ring measurements.
Dendrochronology –	The study of tree-rings. Literally the study of tree time.
DSM –	Digital surface model: area model of land surface, free of ground cover.
DTM –	Digital terrain model: area model of land surface, inclusive of ground cover.
End Date –	The outermost ring measurement in a series where the LYOg ring is absent.
Floating Chronology –	A record with rings representative of undetermined calendar years.
FYOg –	First year of growth: the innermost ring of a measured series.

GCP –	Ground control point. A location of known xyz coordinates used to calibrate UAV recorded data.
GIS –	Geographic information system: computer program designed to model geographic data.
GNDVI –	Green normalized difference vegetation index: Indicator of plant health, sensitive to the chlorophyll content of vegetation.
GNWT –	Government of the Northwest Territories
ITRDB –	The International Tree-Ring Data Bank: A publicly accessible data bank storing dendrochronologies submitted by researchers worldwide.
LYOG –	Last year of growth: A series with a known last year. Most often a trait of cores taken from living trees.
MAD Lab –	Mistik Askiwin Dendrochronology Laboratory
MASL –	Metres above sea-level
Master Chronology –	Amalgamation of dendrochronological series' with ring patterns representative of known years, extending back in time.
NDVI –	normalized difference vegetation index
NIR –	Near infrared: colour outside of the visible spectrum.
NT –	Northwest Territories
PWNHC –	Prince of Wales Northern Heritage Centre
RGB –	red/green/blue: the visible colour spectrum.
Record –	The ring pattern of a living tree, snag, or cross-section, created by combing the measured series'.
Series –	The measured growth pattern obtained from a discrete path or core within a record.
Snag –	Standing dead trees, taken to bridge any gap between the living and archaeological records.

TK –	Traditional Knowledge: Indigenous knowledge passed from generation to generation.
UAV –	Unmanned Air Vehicle
YT –	Yukon Territory

1.0 Introduction and Background

1.1 Introduction

In 2009 a rare archaeological feature, a “caribou fence”, was recorded by Government of the Northwest Territories (GNWT) scientists on the south side of Stelfox Mountain, deep within the Mackenzie Mountains (Andrews et al., 2012). The Moose Horn Caribou Fence system is a complex grouping of at least three fences and one corral structure, conservatively estimated to consist of over 480 individual timbers. During their brief visit, two wood samples were randomly selected from the features for radiocarbon dating. It was understood that ^{14}C dating all of the samples at the site would be cost prohibitive and would not provide the information required to address the questions officials had on the past timing of use and maintenance of the extensive fence system. Therefore, GNWT scientists chose the science of dendroarchaeology to try to understand past use at the archaeological site.

Dendrochronology is the scientific study of tree rings (Speer 2010), with a subdiscipline of the science being dendroarchaeology (Baillie 1982; Čufar 2007; Nash 2002; Sass-Klaassen 2002; Speer 2010). In dendroarchaeology, the measuring of patterns of annual-ring-width variability in an wooden archaeological artifact can be cross-referenced against a chronologically anchored pattern of wide and narrow rings for a given tree species, at a given site. At the Moose Horn Pass site, the anchored chronology was established using living trees near the fence complex, then cross-sections cut from the fences were matched to the living to determine a build date and explore its use history. In this manner, the build date of the object in question can be ascertained.

The Moose Horn Caribou Fence system’s built components have been identified as three distinct features (GNWT 2016), which are here referred to as: major fence, minor fence north, and minor fence south. The major fence is ~800m in observable length and is oriented east/west along a plateau at the base of Stelfox Mountain. The fence then descends from the high plateau down a steep embankment towards Stelfox Creek where it continues into what appears to be a

rounded corral structure. The corral is “J” shaped, with its opening facing upslope towards the high plateau. The minor fences both originate near the western limits of the major fence, following its line and fanning out as they continue eastward. The minor fences do not visibly descend into the valley. The minor-south feature terminates where the plateau gives way to the valley at a point where it appears that slope failure may have impacted the fence’s footprint.

The timbers within the fences are generally well preserved. Where damage is apparent, it appears to have been a result of insect activity and subsequent moisture penetration. Because the archaeological wood is in such good condition, the site was identified as a suitable target for dendroarchaeological analysis focused on placing these independent features in time.

The project was conceived of as part of a total-recording effort initiated by GNWT “Cultural Places Program” (CPP), based in Yellowknife NT at the Prince of Wales Northern Heritage Centre (PWNHC). CPP staff proposed a hybrid “proof of concept” project combining unmanned air vehicle (UAV) imaging, with dendroarchaeology to visually record the site and its age(s). The site has been identified as “at risk”, the project therefore serves as an archaeological mitigation effort. Secondary outcomes include an exploration of site function, contributions to the Canadian Subarctic dendrochronological record, and suggestions for future social and natural science research.

The site is located in the Tulita District of the Sahtu Settlement Area, the traditional territory of the Shúhtagot’ine (Mountain Dene) people. There exists a significant relationship between the Shúhtagot’ine, the landscape and its resources, caribou being one of the most important. It is the goal of this project to address research questions that will provide information valuable to modern Shúhtagot’ine regarding the ways in which their ancestors utilized the landscape, and how the local environment may have changed over time. To accomplish this end, remote sensing data, reflecting localized differential soil conditions, were evaluated to assess the spatial relationships of the differential soil conditions, and were compared to dates derived from spatially associated points along the fence line.

1.2 Importance of Caribou to the Shúhtagot’ine

The modern caribou (*Rangifer tarandus caribou*) community in the region belongs to the Redstone herd (Galloway et al. 2012; Larter 2012; Letts et al. 2012; Wilson and Haas 2012), which remains either in, or on the margins of, the mountain environment throughout the year.

The Redstone migration pattern can be described as east/west, wintering in the lowland, wooded ranges of the eastern Mackenzie Mountains and summering in the alpine environment to the west near the border with the Yukon Territory (Galloway et al. 2012, Wilson and Haas 2012). Movements between the two locales include a diurnal pattern, alternating between higher and lower elevations (Ion and Kershaw 1989).

Caribou are vital to the Mountain Dene way of life (Bayha 2012). Not only are they central to the subsistence economy, they are a key component of oral history passed from generation to generation, teaching how the relationships that have endured through time, came to be.

Modern Dene residents of the areas in and around Dehcho are concerned about external factors like climate change and non-resident hunters, and what effects they will have on caribou population and movements (Sahtu Land Use Planning Board 2010). Perhaps more importantly, there is a concern regarding whether or not future generations will maintain the connection to the land. By incorporating the results of a dendroarchaeological research program to existing knowledge of a hunting technique that was so important to their ancestors, it is possible that the Sahtu youth will gain a deeper understanding and appreciation of their ancestors, and of the knowledge passed from generation to generation via oral history. A by-product of dendroarchaeology is a tangible piece of history that can be seen and touched (the discs cut from the fence itself). It is not an abstract concept to be pondered, but a physical representation of the ancestors and their activities during recent, and far distant times.

The hope is that by combining Traditional Knowledge (TK) and modern science, a greater understanding of the relationships with the land will be achieved, and that the youth of today will be inspired to explore their ties to their ancestors.

1.3 Dendrochronology

Dendrochronology is the scientific study of tree rings (Speer 2010), literally translating to the study of tree-time (Haury 1935). It gained prominence in North America in the early 20th century as an archaeological tool thanks to the efforts of A.E. Douglass. By dating archaeological sites in the Southwestern United States Douglass (1929), provided the first scientific method of

specifying absolute dates of wooden artifacts and features. Prior to his work, relative dating was the only option available for dating the material remains of past cultures.

The science relies on trees living in a seasonal environment, which results in annual growth and dormant periods, necessary for annual-ring development (Fritts 1976). Also required is some type of external limiting factor shared within the local tree community, which causes similar annual variation in the ring widths of all trees in a given area. It is this pattern, reflected in wide/narrow variation in the ring sequences that provides the time-fingerprint of a chronology.

1.4 Principles of Dendroarchaeology

Dendroarchaeology at its most basic level is accomplished by first determining the pattern of growth of living trees in an area, a living chronology with each ring attributed to a specific known calendar year (i.e., the last complete ring formed during the year prior to it being cored). Then a ring pattern observed in archaeological wood is obtained, a sequence of unknown age called a “floating chronology” (sequence floating in time), which can then be pattern matched, or crossdated, to the chronology of a known timeline. Crossdating is the fundamental principle of dendrochronology (Douglass 1941; Maxwell et al. 2011; Speer 2010), without which, the discipline of dendroarchaeology could not exist.

1.5 Dendroarchaeology in Canada

Dendroarchaeological methods in Canada have been utilized to date historic structures associated with European settlement (Dick et al. 2014; Querrec et al. 2009; Robichaud and Laroque 2008; Selig et al. 2007; Young-Vigneault et al. 2012), westward expansion and economic activity (Brelsford 2001), and those of Indigenous design and construction (Smith et al. 2005; Young and Laroque 2009). This is by no means an exhaustive list, but is indicative of a trend reflecting the application of dendroarchaeology in the southern regions of Canada.

Northern sites, on the other hand, have received little in the way of dendroarchaeological study, and those that have, although comparable, are located in the United States. Research in Alaska saw the pioneering work of James Louis Giddings in the early 20th Century (Nash 2000), but little, if any, focused entirely on the built history of Arctic/Sub-Arctic Indigenous populations, with only one project making the attempt with mixed success (Blazina-Joyce 1989).

In two instances, dendroarchaeology has been identified as a suitable tool for providing dates for northern fence structures (Stanley Van Dyke, personal communication 2017; Warbelow et al. 1975). The work of Blazina-Joyce (1989), being the first of its kind, did serve to provide some idea of how the current study could proceed, despite her work being quite different in scope from that undertaken here.

Blazina-Joyce's (1989) research focused on the caribou fences of Northeastern Alaska, yielding 18 dates from three sites, with one fence dating to the late 1700s, 16 to the 1800s, and one to the 1900s. Blazina-Joyce did not sample the features, conduct the empirical analysis of the cross-sections, or analyze the cores. The current project does not suffer from these inconsistencies in data acquisition, processing, and analysis arising from multiple people working on the project, as all aspects of the Moose Horn Pass study were conducted by the author.

At the time, Blazina-Joyce (1989) did express the need for a greater number of samples than were obtained in her study, as that might provide date clusters from which use history could be better inferred. It is with this in mind that the Moose Horn Pass research was designed. The main researcher was actively involved throughout both field seasons, and processed, measured, and analyzed all samples. This degree of involvement allowed for a dynamic approach, capable of providing a more complete outcome. The most notable obstacle anticipated was the absence of rings indicative of the year in which a given tree died. In such an event, the outermost ring provides a bracketing date, after which a construction or repair event could have occurred.

The Moose Horn Pass Caribou Fence is the first dendroarchaeological project of its kind, if not in Canada, then certainly in Canada's subarctic. It is the first dendroarchaeological project to incorporate Unmanned Air Vehicle (UAV) surveys as a component of the overall tree-ring analysis. The application of UAV technology was essential to overcoming obstacles associated with the project, such as its remote location, the incredible expense of visiting it, and the limited time spent on the ground, which was focused on collecting cores and cross-sections. Remote sensing data provided a means to evaluate the landscape, the physical extent of the archaeological features, and spatial relationships. Baillie (2002:71) wrote that in dendrochronology "...everything reduces to either pioneer work or dating application". This project is both. Lessons learned from past work are augmented by modern technologies, making the contributions of this

project to the archaeological and dendrochronological records of the region significant, and unique.

1.6 Drive Fences/Drift Lines

The features (Figure 1. 1), identified as “caribou fences” were built and used by past hunters to guide animals to specific areas for harvest. This method of communal hunting is relatively common throughout time and across cultures, especially as related to the mass communal harvest of ungulates (Brink 2008, 2013; Frison 1998; Kendrick 2000; O’Shea et al. 2013, 2014; Parsons 2015; Reeves 1998; Smith 2013; Van Dyke 1975).

The remnants of this type of site tend to be represented by stone cairns in the archaeological record as those constructed of wood either decomposed long ago, or deteriorated to such an extent that their study would have very little utility. The caribou fences in this study spend most of the year frozen, and under snow. Many of the timbers within the features exhibit very little in the way of decomposition, and have therefore been identified as well suited to a dendroarchaeological assessment.

1.7 Study Area

The site is located on a plateau at the base of Stelfox Mountain (63.527777 N, - 127.741944 W) (Figure 1. 2). Two small water bodies, with stunted bushes around their shorelines, are in immediate proximity to the archaeological site. At the easternmost edge of the plateau, the fence descends approximately 48 metres towards Stelfox Creek, the lowest point of the corral feature.

1.7.1 Geology

Stelfox Mountain is part of the Cordilleran Orogen (Sahtu Land Use Planning Board 2010) which is situated within the geological formation known as the Windermere Supergroup (Aitken 1991). Regional geology consists of outcroppings of bedrock, glacial till, and alluvial fans (Auld and Kershaw 2005). The Stelfox Mountain geology consists of diamictite, overlain by dolostone, quartz sandstone, and shale (Aitken 1991; Hoffman and Halverson 2011). There are no obvious geologic outcroppings near the fences, with most of the ground surface appearing to be the result of alluvial deposition. However, there are several “mineral occurrences” (Ootes et al.



Figure 1. 1 - Facing north, Stelfox Mountain in the background, and a section of fence in the foreground.

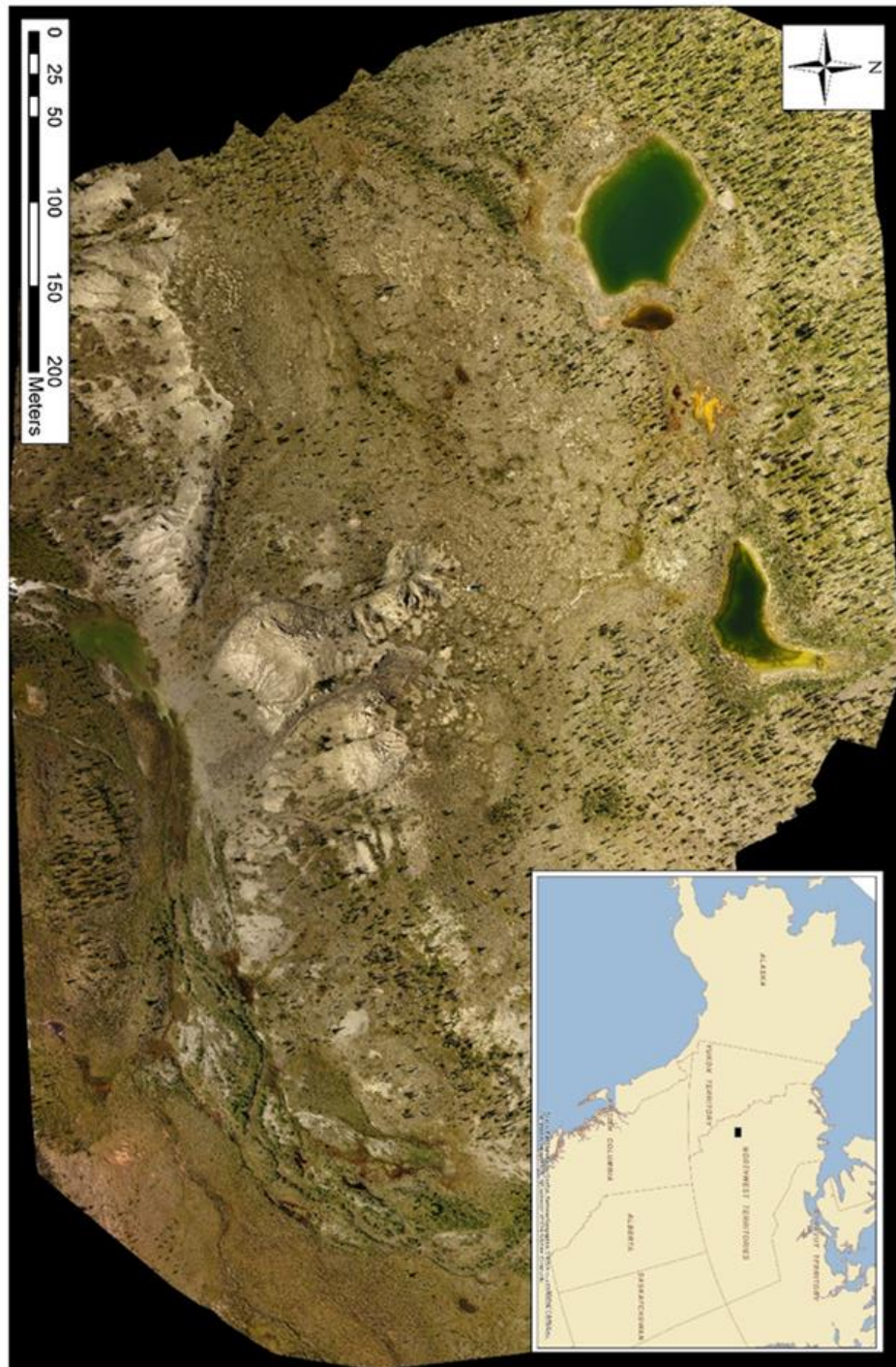


Figure 1. 2 - The plateau and valley to the south of Stelfox Mountain, the study area where the Moose Horn Pass Caribou Fence is situated.

2013: Figure 2) in the area, which may be a significant factor in the area being well situated for successful caribou hunting (Andrews et al. 2012).

1.7.2 Climate (and seasons)

Stelfox Mountain is a relatively inaccessible location with no weather records directly from the site. Based on records from nearby locations (MacMillan Pass YT and Wrigley NT) the growing season lasts for approximately three to five months depending on the given year's conditions. The study area is south facing and receives unimpeded sunlight for a large portion of the growing season. In general, subarctic-alpine areas typically experience high snow, high wind, and significantly cold conditions through much of the year.

The Sahtu region experiences average January temperatures between -20° C and -30° C (Auld and Kershaw 2005), with the area around Moose Horn Pass estimated to have a February daily high at -30° C (Auld and Kershaw 2005), with an annual mean daily temperature of -6° C (Auld and Kershaw 2005). The Sahtu's alpine environment receives approximately 700 mm of moisture in annual precipitation, much of it as snowfall during the winter months. Snowfall amounts are higher within the mountains, with Stelfox Mountain receiving more than areas to the east and west (Auld and Kershaw 2005).

1.7.3 Vegetation

Scientific survey of local vegetation was not undertaken as part of this research. This summary is the result of cursory observations while on-site. White spruce (*Picea glauca*) trees dominate the study area, though a very few deciduous trees are beginning to colonize disturbed slopes in the valley below. Small shrubs and bushes are present in the areas surrounding the water bodies adjacent to the fence complex. The plateau on which the fence is situated is characterized by grasses and forbs, with a small number of white spruce trees present.

1.8 Methods

Dendroarchaeological methods were employed to determine the ages of the sampled fence timbers, so as to determine the use-life of the fences, and whether use was continuous or sporadic (see also Section 2.4).

Maps derived from UAV-obtained remote sensing data were used to display archaeological end-dates within the fence lines, and to model physical environmental features and potential relationships with fence use and design (see also Section 3.4).

1.8.1 Tree-Ring Analysis

The following is a brief summary of the key points of dendroarchaeological research. Types of ring anomalies that presented challenges when conducting analyses will be introduced.

1.8.1.1 Measurement

Following standard dendrochronological procedures, ring widths were measured to .001 mm accuracy using a Velmex stage system, captured using J2X software, and checked for signal homogeneity with COFECHA. The resulting master and floating chronologies were pattern matched, allowing for specific end dates to be assigned to each sampled timber within the fence system.

“Last year of growth” (LYOG) refers to the most recent complete ring of an individual tree or sample. For living trees, and those otherwise exhibiting a known final year, LYOG equates to a defined calendar year. In cases of archaeological wood, or snags that do not exhibit such traits, LYOG becomes the most recent ring measured, or “end date”.

1.8.1.2 Crossdating

Dendrochronological crossdating is most effective when rings are sensitive to conditions within their environment. All things being equal, trees experiencing identical growing conditions, with little year-to-year climatic variance, will deposit near identical ring patterns from year-to-year, termed “complacent rings” (Stokes and Smiley 1968). The presence of one or more limiting factors increases the ring pattern variability from year-to-year and creates patterns that are termed “sensitive rings” (Stokes and Smiley 1968). These sensitive rings tend to be able to be matched more specifically in time.

Speer (2010) wrote that visual crossdating is the first step in crossdating, with the results checked for statistical significance with program COFECHA as a second. One method of visual crossdating, developed by A.E. Douglass (1941) consists of a subjective analysis of individual ring patterns that are manually graphed and then compared against graphs of ring series from others in a chronology, this is referred to as a skeleton plot. Marker years (Dick et al. 2014,

Szeicz 1996), years that uniformly exhibit traits consistent with poor growing conditions, are important using this method. To enable the dendrochronologists to revisit discrete years within an individual sample, the core itself is commonly physically marked to denote year, decade, and century.

Other modern methods of visual crossdating are practiced, with only minor variations in execution between the new and the old. In this study, skeleton plotting and physically marking the cores was not possible. The size of the rings, even those that might be considered relatively wide, precluded any attempt at unaided crossdating.

Measurements of living trees were checked for accuracy using the computer program COFECHA, which checks for the strength of correlations between ring patterns. As the living trees all share the same LYOG temporal anchor, it was assumed that patterns would be similar throughout their overlap. Apparent anomalies were then revisited to determine their nature, and addressed as necessary. Individual trees often exhibited differential growth within a given year, which meant that a lower correlation was accepted. Ensuring that those years were indicative of anomalous growth required observing markers on either side of the year in question. The marker was often damage caused by an external factor, most often a freezing event that occurred at some point during the growing season, but did not have an overall effect on that year's growth. Freezing causes cells to crush due to water expansion, an easily identifiable trait. In this way, visual crossdating was used to confirm the initial computer assisted check.

1.8.1.3 Program COFECHA

Program COFECHA provides measures of statistical goodness-of-fit between samples, to test if the ring pattern of one sample matches the overall pattern of all other samples in a group (Grissino-Mayer 2001, Holmes 1983). The program divides each individual series into time segments, the length of which is determined by the user, and this dictates the amount of overlap that segments have with one another when pattern matching the individual series. The output of a run includes each individual tree's correlation with the overall group chronology, made up of all the other samples from the site. The program also generates "flags" for segments that are not correlating well with the group and that might have a higher correlation value if they were to be moved elsewhere in the time series (from -10 to +10 years). This process can assist a user in determining where certain anomalies may exist, or where human error in ring measurement may

have occurred. The flag may also indicate that the segment's correlation is "highest as dated", but with a correlation value falling below a required threshold level, which is traditionally set at the 99% confidence interval; in the current analysis, COFECHA calculated the 99% confidence interval value as 0.3281.

1.8.1.4 Ring Anomalies

The Stelfox Mountain trees do indeed exist in a limiting environment, with several factors impacting the growth of trees throughout the sampling area. The ring widths exhibit several types of anomalies as a result of these conditions.

1.8.1.4.1 Micro Rings

A micro-ring is an annual ring that is very small, perhaps only one or two cells in width (Speer 2010). In some extreme cases, these micro-rings can occur consecutively for decades, creating a sequence of very small rings (Figure 1. 3). When this occurs, accurate measurement is not always possible. Unfortunately, this type of ring was commonly seen throughout all sample types analyzed (live, snag, archaeological) as part of the current study. Although they provided a unique growth pattern, they proved very problematic to analyze.

1.8.1.4.2 Locally Absent Rings

These rings occur when an annual-growth ring does not form around the entire circumference of the stem (Schweingruber 1996). This may occur due to insufficient inputs being available, such as access to water, sufficient sunlight, or because of increased competition, because cells were deposited as reaction or compression wood (see below) covering discrete segment(s) around the stem (Figure 1. 4).

Locally absent rings were a common feature throughout all of the sample types analyzed for Stelfox Mountain. High winds, tree location, slope failures, soil creep, and possible avalanche activity are all factors in the occurrence of locally absent rings. The forest community at Stelfox Mountain would have been influenced by these processes for as long as the trees were present.



Figure 1. 3 - Micro-rings. Prud'homme, Saskatchewan white spruce (top) versus Stelfox Mountain, Northwest Territories archaeological wood (bottom).

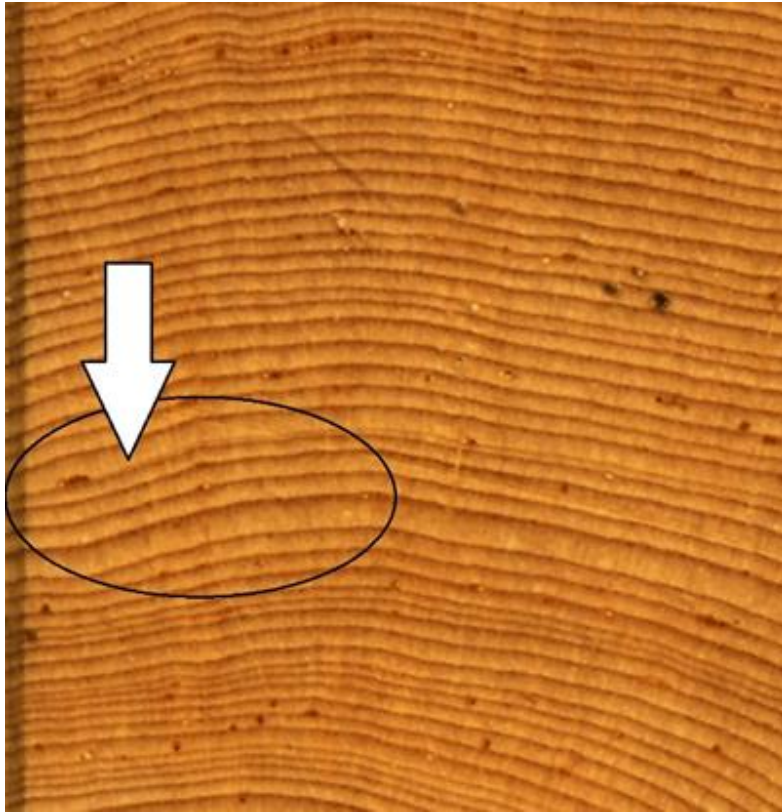


Figure 1. 4 - Locally absent rings. Arrow indicates where two rings merge into one, resulting in the absence of one ring elsewhere around the stem.

Correcting individual sequences to account for locally absent rings represented a significant investment of time and effort. Determining the ring absences in individual samples was integral to developing an accurate site chronology at Stelfox Mountain, and, ultimately, being able to date archaeological wood from the caribou fences.

1.8.1.4.3 Compression/Reaction Wood

The white spruce, a gymnosperm (Speer 2010), uses compression and reaction wood to maintain, or re-establish vertical orientation when circumstances require it (Schweingruber 1988). Both compression and reaction wood act to perform the same functions, but are responses to different causal factors. Compression wood occurs as a fairly consistent feature of ring patterns observed in trees growing on an incline. Reaction wood, as the name suggests, is a response to some discrete external factor, and is not generally a feature consistent throughout the tree's growth record. Throughout this manuscript "compression wood" will be used to refer to trees growing on inclines, while "reaction wood" will refer to those rings deposited in response to some external event.

This type of cell deposition (Figure 1. 5) distorts the regular pattern of growth as the rings are significantly wider in the direction of the lean, than would usually be found. All of a year's growth cells might be deposited in this way, depending on the correction required. This commonly results in the occurrence of locally absent rings. It is possible to navigate through such occurrences when working with a cross-section as the entire stem is visible and paths can be adjusted to avoid the anomalies. Cores do not provide this opportunity, as whatever was cored is all that is available to view. This is why two cores are commonly taken per tree, and why trees growing on slopes are classically cored perpendicular to the direction of the slope. A core taken from the downslope side would tend to exhibit ring measurements skewed by compression wood, while the ring measurements from the upslope side may be missing several years' worth of ring growth due to locally absent rings. The growing environment the trees at Stelfox mountain are, or have been, subject to all of the processes required to produce compression and reaction wood. As such, very few samples do not exhibit some degree of distortion because of unequal cell distribution around the stem.

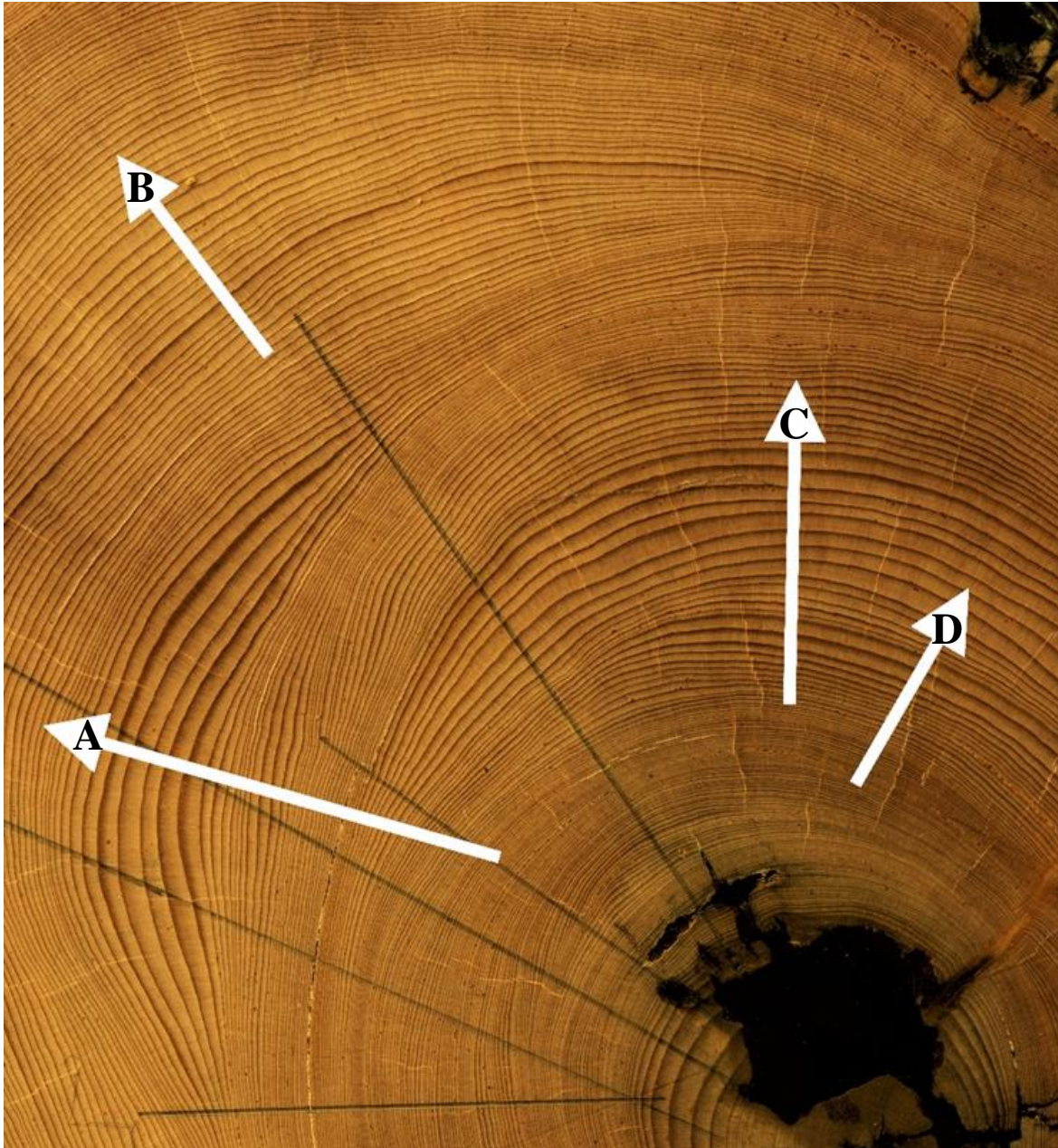


Figure 1. 5 - Reaction (A,C,D) and compression (B) wood.

1.8.1.4.4 False Rings

False rings have an appearance similar to that of latewood, the dark part of an annual ring that denotes the end of that year's growth (Schweingruber 1996) (Figure 1. 6). In fact, they are identical to the early stages of latewood, but occur when the tree has interpreted an external limiting factor to be signalling the end of a growing season, such as a period of decreased temperature consistent with a change of season. Once conditions return to normal during the growth year, the tree switches back to growth mode, leaving a small dark irregularity within the season's ring.

In this study, these growth aberrations were usually easy to identify, but they were problematic when appearing in sequences with high numbers of micro rings.

1.8.1.4.5 Damaged Rings

Damaged rings occur when a significant event occurs during the growing season. In the Stelfox assemblage, the damage is usually an extreme outcome of a freezing event during the growing season. They are identified by a series of damaged cells, crushed by freezing water (Speer 2010) within the developing layer (Figure 1. 7). In some cases, material is missing covering one or multiple years. The embolism can interfere with identifying nearby rings, as the distortion quite often carries on past the affected ring. As with other phenomenon, it is easy to work around the issue when measuring cross-sections, but not as easy when dealing with increment cores.

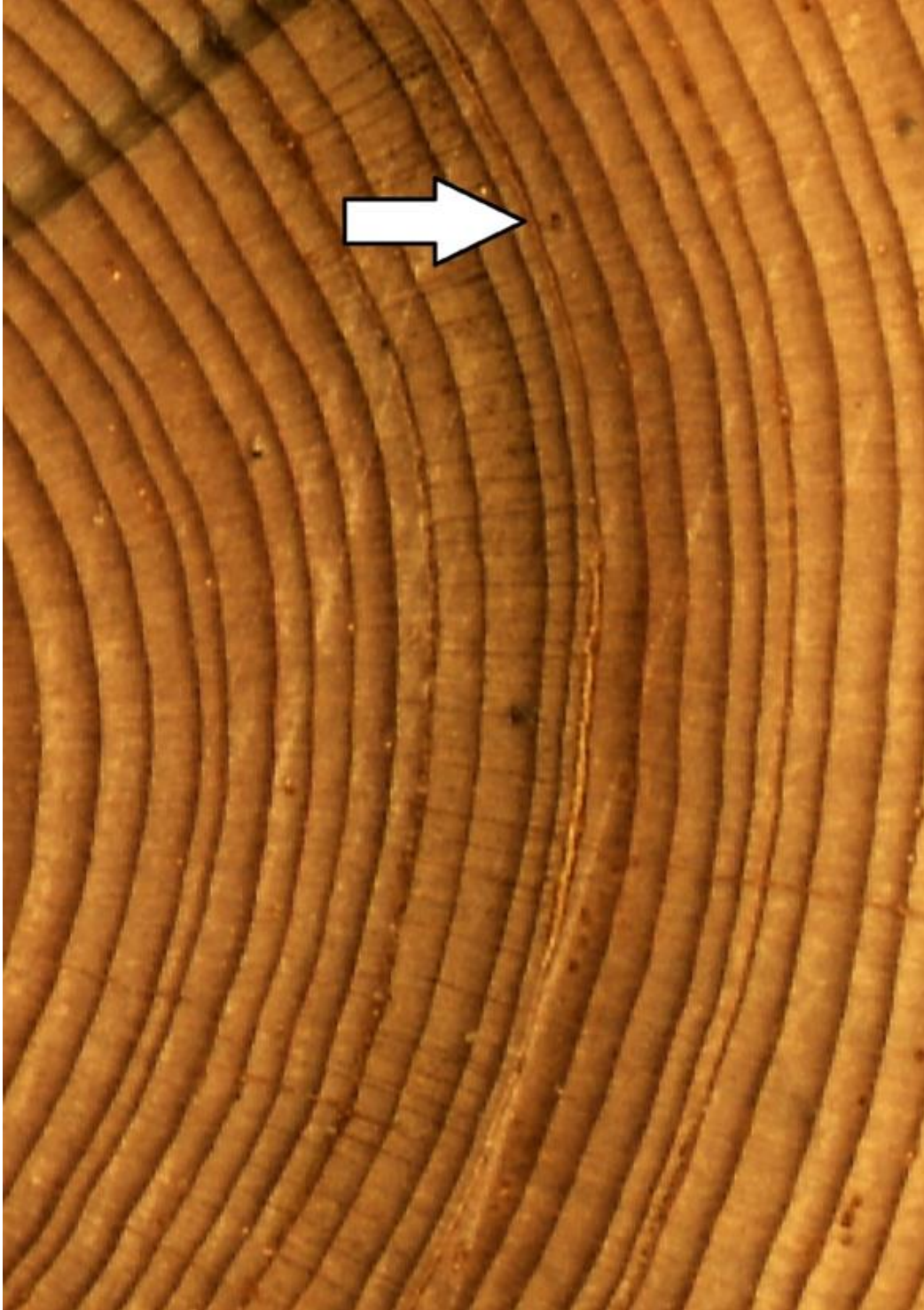


Figure 1. 6 - False ring, marked by white arrow. The ring appears as though it is a latewood boundary, but in fact is the result of a limiting factor causing stress to the tree at some point during the growing season.



Figure 1. 7 - Arrows indicating frost damaged rings within a sample. Note the cells are large, indicative of an embolism from frost shattering of cells.

Unseasonal frosts were observed to be a common occurrence affecting the Stelfox assemblage. Because a frost would be experienced by all trees in the area, prominent damaged rings were often used to visually crossdate sequences when marker years throughout the series were not a viable method of crossdating.

1.8.1.4.6 Missing Rings

If conditions are such that growth is severely impeded, a tree may fail to grow at all during a year (Figure 1. 8). This can be the result of a tree being so young, or so old, that it is unable to withstand events that will limit their growth, such as lack of water, insufficient sunlight, increased competition, or extreme cold. The anomaly can also be caused by a snowpack being so massive that it remains throughout the year, completely covering smaller trees. The trees that survive the event will exhibit a gap in their sequence representative of the missing growth period.

This phenomenon was not a common occurrence within the Stelfox Mountain chronologies, but it did present a significant hurdle to overcome when it did occur. The gaps in time could not be properly understood without several samples all determined to have specific marker years present, as well as having a continuous record of ring pattern before and after the missing period, to allow for the paths to be matched to either side of the anomaly.

1.8.1.5 International Tree-Ring Data Bank

The International Tree-Ring Data Bank (ITRDB) is a web-based collection of tree-ring data submitted by dendrochronologists from around the world. The databank is hosted by the United States' National Centers for Environmental Information (NCEI). Data are available for download by anyone that wishes to access it. A .kmz file is also available for download that, when opened, plots the worldwide locations of all sites in their inventory. Using this tool, I determined that no dendrochronological studies had taken place within 160 km of Stelfox Mountain.

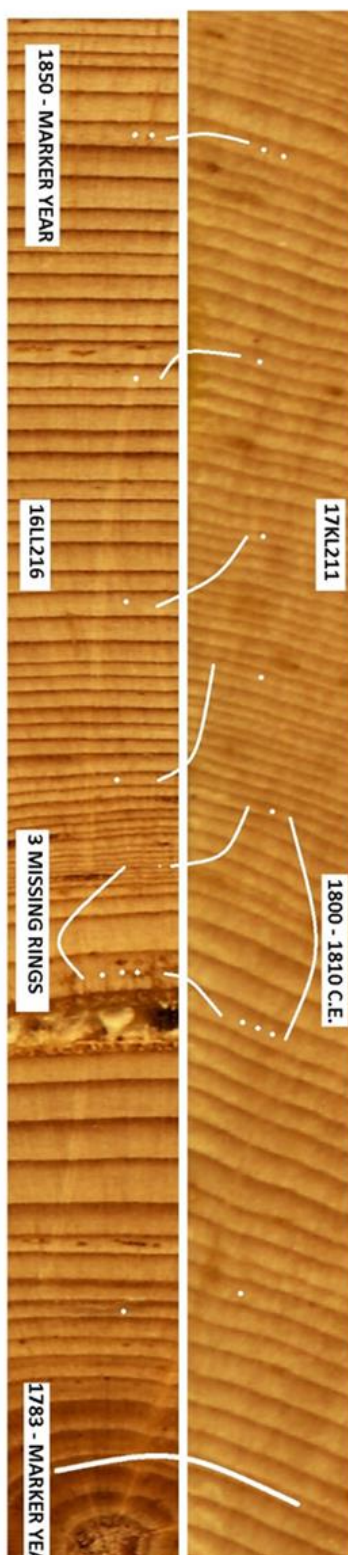


Figure 1. 8- Absent rings indicated by a difference in total ring counts between discernable markers on either side of the affected sequence.

For comparative purposes, the raw data for the two closest sites to Stelfox Mountain (Mackenzie Mountains to the north, and Kuskula Creek to the south) were obtained (Figure 1. 9). Authors of these analyses treated their data sets in the same way as the data collected in this study and consequently were available to be plotted and visually compared with the Stelfox series. This was conducted to achieve a measure of quality control, and to help evaluate the accuracy of the Stelfox chronology.

1.8.2 UAV Analysis

Data complimentary to the dendroarchaeological aspect of this research were provided using UAV remote sensing. The data were acquired using an unmanned air vehicle equipped with a multi-spectral sensor array, which provided images that were invaluable for visualizing and evaluating the physical structure of the fence complex, and the surrounding landscape. The specialized equipment (Figure C. 1) and operator (Figure C. 2) were supplied by the University of Saskatchewan's Mistik Askiwin Dendrochronology Laboratory (MAD Lab).

1.8.2.1 Type of UAV

Transport Canada (2014) classifies UAVs as a power-driven aircraft, other than a model aircraft, that is designed to fly without a human operator onboard. In this study, a DJI Phantom 4 UAV equipped with a high resolution RGB camera as well as a multispectral (green, red, red-edge, and near infrared wavelengths) Parrot Sequoia™ sensor was used to capture video of the major fence and the surrounding area, as well as overlapping images in both the visible (RGB) and near-infrared (NIR) formats. The static images were combined using Pix4D software that allowed the creation of a 3D model (Figure 1. 10) of the site, as well as high-resolution mosaics that permitted the evaluation of the site's physical properties well after the fieldwork was completed. The overlapping still images were differentially corrected to ± 2 cm resolution.

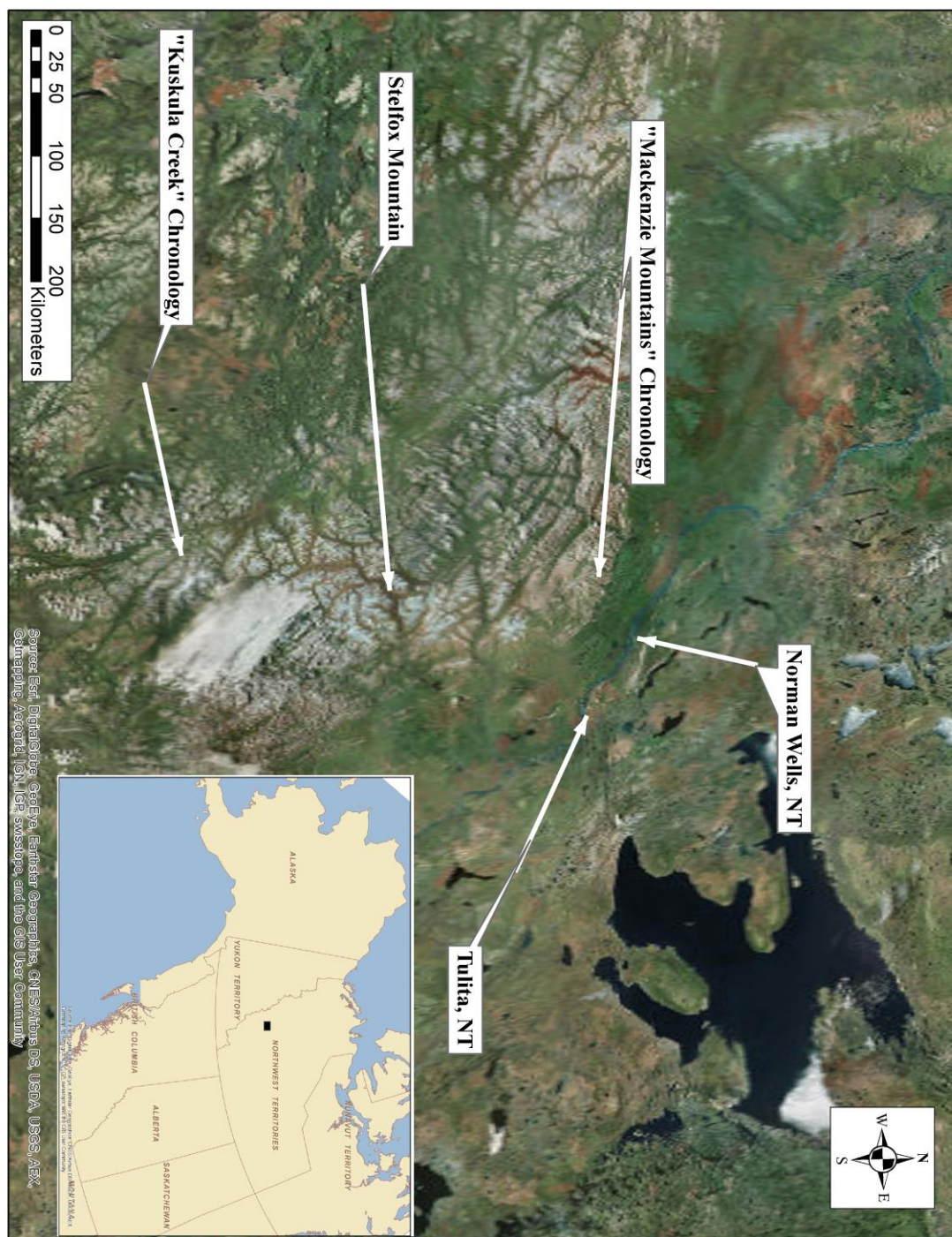


Figure 1. 9 - Stelfox Mountain, and the locations of dendrochronological studies used as comparisons against the chronology developed at Stelfox Mountain.

1.8.2.2 Multispectral Analysis

Different UAV based analyses included those focused on elevation, micro-topography, as well as vegetation indices like normalized difference vegetation index (NDVI) and green normalized difference vegetation index (GNDVI). The different indices were used to determine relative differential health of plants or grasses proximal to the fence, which might indicate if the plants had been subject to different physical effects than their neighbours, such as differential soil conditions, or historical access to water.

NDVI values are generated using both the visible (RGB), and invisible (NIR) spectrums. The result is a value between -1 and +1 that is indicative of plant health within a study area.

$$\text{NDVI} = (\text{NIR} - \text{Red}) / (\text{NIR} + \text{Red})$$

GNDVI also uses multi-spectral data in its calculation. It is a variation of the NDVI, more sensitive to the chlorophyll content of the plant community. Like NDVI, its output is a value between -1 and +1 that indicates overall plant health.

$$\text{GNDVI} = (\text{NIR} - \text{Green}) / (\text{NIR} + \text{Green})$$

Once the overlapping images containing the multispectral data were combined, the dataset permitted the evaluation of vegetation and soil characteristics by the visualization of NDVI and GNDVI indices (Figure 1. 11). The goal was to determine if vegetation changes along the fence lines might reflect legacy effects due to the potential trampling of caribou herds through time (c.f., Morneau and Payette 2000; Stark et al., 2010). Thus, the method was intended to help characterize where the effects of repeated animal trampling may have been transferred to the soil system through compaction (Freschet et al. 2014; Mapfumo et al. 1999; Startsev and McNabb 2009), illustrated today by the vegetation assemblages growing adjacent to the fences.

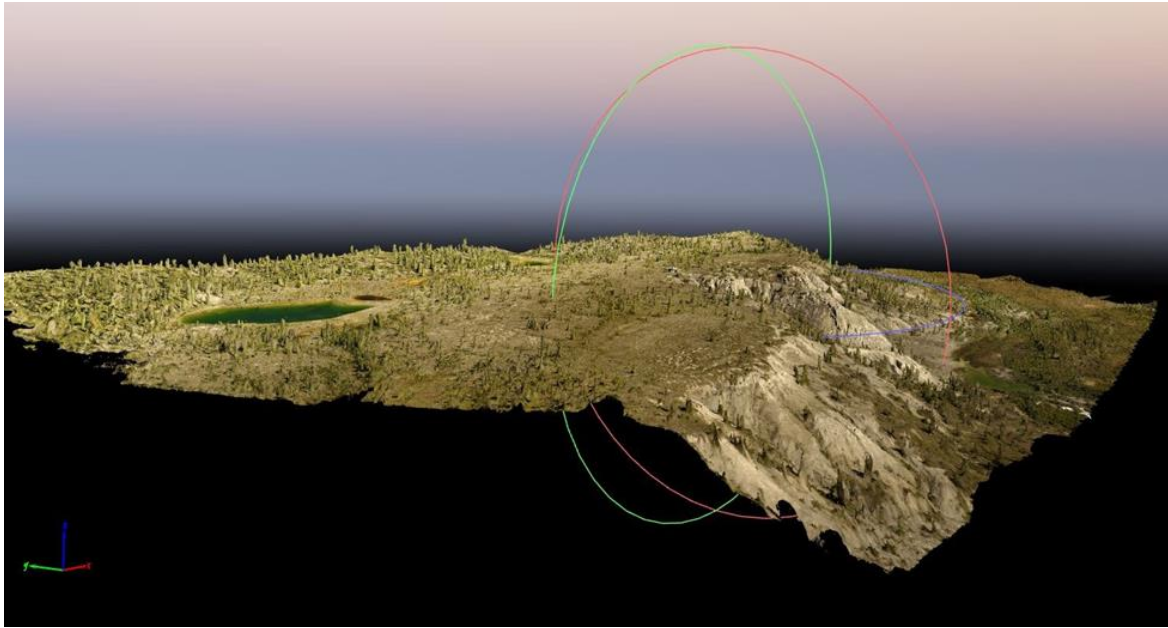


Figure 1. 10 - Screen capture of Pix4D 3D model. Arcs reflect the axis by which the model can be manipulated.

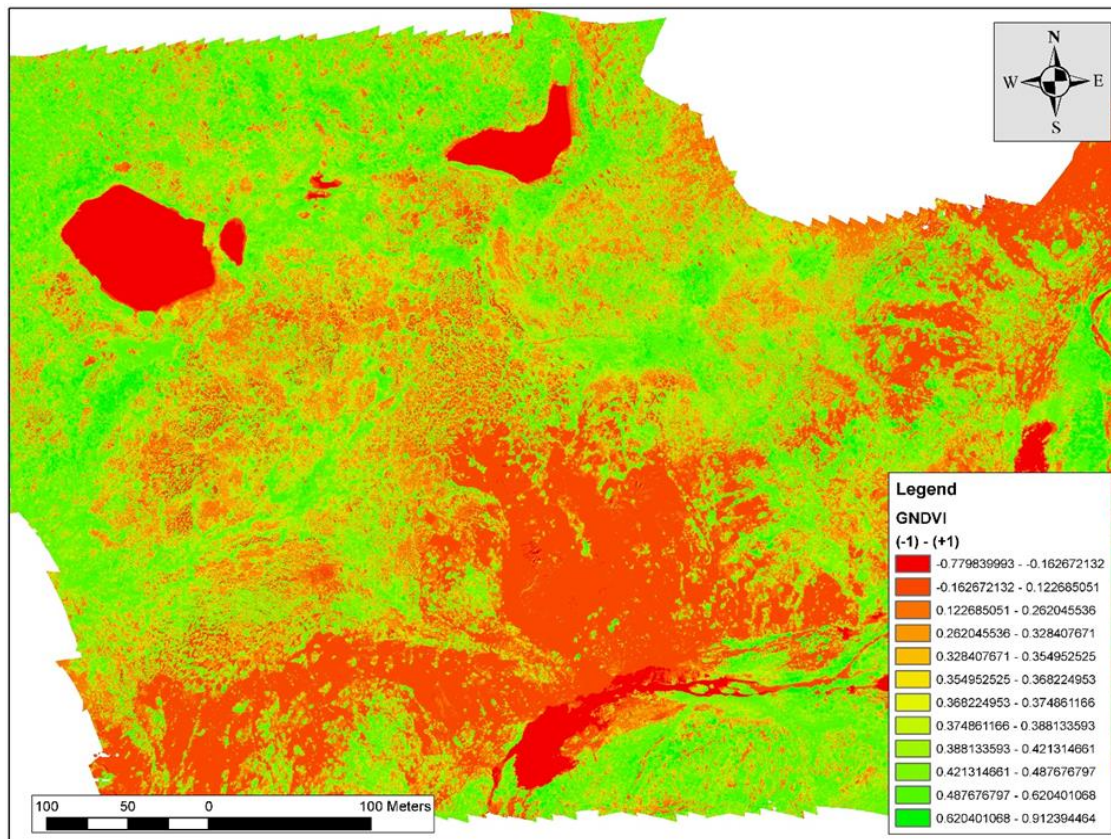


Figure 1. 11 - GNDVI values mapped onto research site at 2.72 cm/pixel. Red (lowest values) indicates an absence of vegetation and the darkest green (highest values) indicate healthy / thick vegetation.

1.8.3 ArcGIS Analysis

ArcGIS is a software platform designed to implement a geographic information system (GIS) approach to data analysis. Using the mosaic created with Pix4D as a base map (Figure 1.12), different datasets can be integrated using ArcMap 10.5 (part of the ArcGIS toolset). Data can either be combined with, or be independent of, other data. In addition to the data, layers can be manually created and added to the mosaic to aid in the analysis, or to create the visual representations necessary for disseminating findings. For example, fence lines can be drawn, areas of particular interest can be delineated, and anything that might need to be conveyed outside of what had been captured visually, can be added in a new layer.

In this project, analyses included vegetation indices, relief, micro-topography, and adjustments of 4-band imaging to highlight features that were otherwise not visible. The ArcGIS platform also allowed the dendroarchaeology data to be displayed in space and time. In its most basic application, each cut date with its specific geographic coordinates were accurately positioned within the fence systems.

1.8.3.1 Elevation Modelling

It is well documented that subsistence hunters typically took advantage of local physical features to complement their built components (i.e., fences and drive lanes) (Andrews et al. 2012; Bergerud et al. 1984; Blazina-Joyce 1989; O'Shea et al. 2013; Reeves 1998; Smith 2013; Speth 2013; Warbelow et al. 1975). To explore this facet of hunting strategy, elevation modeling was applied to explore probable past land and water conditions, and how they may have impacted fence use and design from its earliest to most recent use periods. In this study, the UAV was given a ground control point (GCP) which acted as a home base, and the focal point from which all images are located using XYZ coordinates. Over the course of the flight run, a beam is emitted towards the ground, that is reflected back to the sensor onboard the UAV. The speed at which it returns indicates the elevation of the discrete XY coordinate targeted. The resultant XYZ data were configured to display as either a digital surface model (DSM) or digital terrain model (DTM); the former being a model free of any physical obstructions (i.e. trees, buildings, etc.),

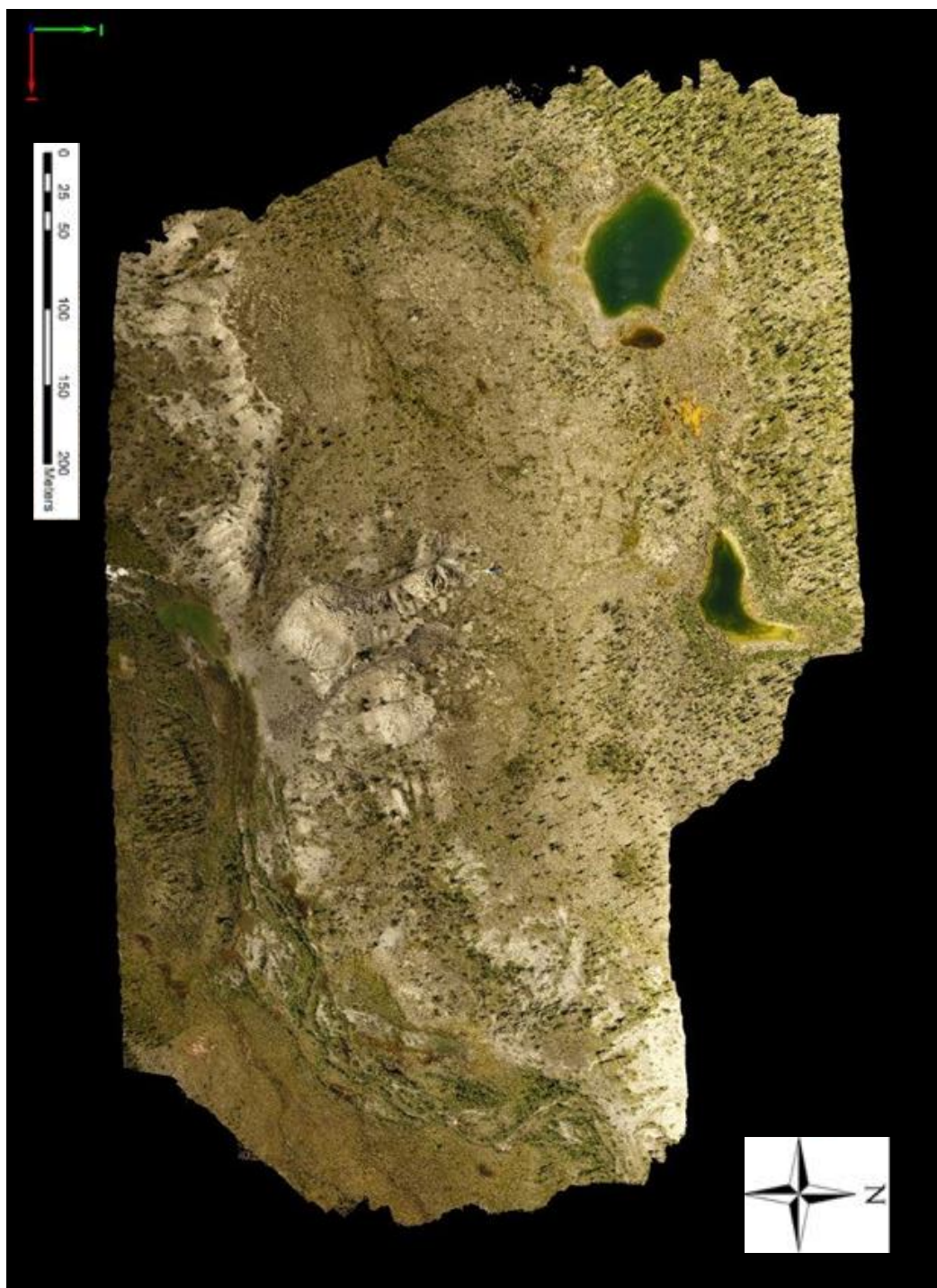


Figure 1. 12 - Screen capture of Pix4D RGB orthomosaic. Specific details and mapping elements are added after export to mapping program like ArcMap.

with the latter being inclusive of any features present in the target area. The DSM layer was most suitable for exploring the site and evaluating its topography on macro- and micro-scales (Figure 1. 13).

Combining the DSM with the orthomosaic and vegetation indices allowed for different ideas to be posited regarding the site's past physical environment, and the fences' diachronicity relative to the changing landscape.

1.9 Research Objectives

As indicated above, it is the goal of this project to place the fence's use-life in time, which is one aspect of the total-recording effort initiated by the GNWT. The project was designed so as to provide data that would illustrate when, why, and how modifications were made to the fence system. It was also anticipated that such results were likely to indicate the fluidity required to effectively respond to an ever-changing environment. Such results might also provide the modern Shúhtagot'ine community with another way in which they can connect with their ancestors, as the fence system is evidence of the intimate knowledge the ancestral Shúhtagot'ine held regarding their land, and the symbiotic nature of their relationship with it.

This research is based on the hypothesis that the use of the site was a direct result of the region's meat-trade economy of the late 19th/early 20th centuries. The alternative being that site use precedes the 20th century meat trade. Further, multiple dates would be consistent with the fence being reconfigured over its use-life to best assist the harvests that had taken place through time. To evaluate the hypothesis, clusters of dates were required to overcome any misleading dates that may present themselves because of repair and maintenance and/or the use of deadwood in any aspect of its construction.

1.10 Organizational Summary

This thesis is presented in a manuscript format, with chapter one describing the problem and the background. Chapters 2 and 3 are presented as stand-alone, independent manuscripts. There will therefore be some degree of repetition between the chapters, but every effort is made to minimize overlap where possible. Chapter four will summarize the conclusions of the previous chapters, and discuss the results provided by combining the multiple datasets.

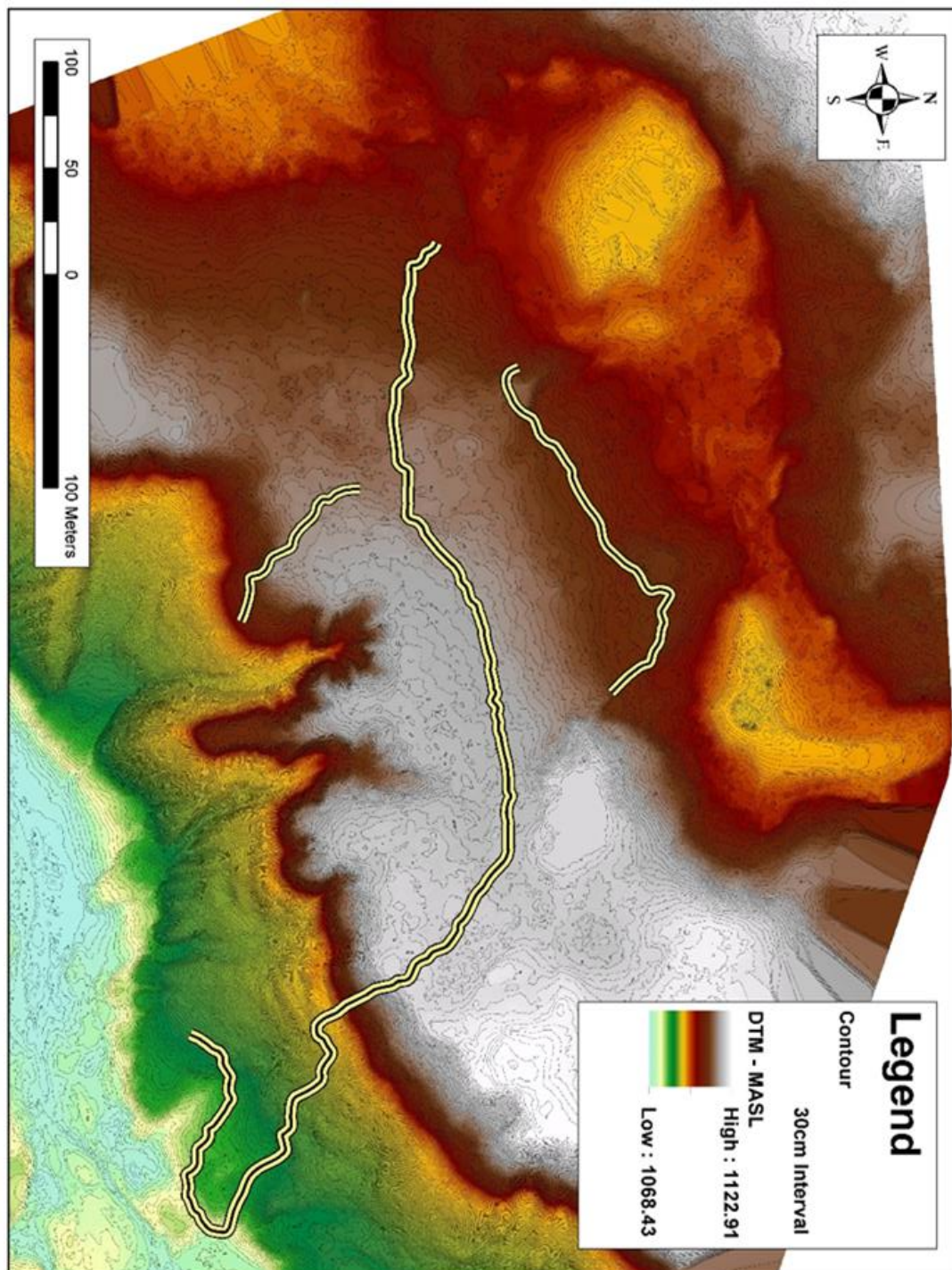


Figure 1. 13 - ArcMap elevation model; 30cm contours (micro) and DTM of site (macro).

2.0 Title of Manuscript: Dendroarchaeology of the Moose Horn Pass Caribou Fences

2.1 Abstract

A wood constructed fence complex, of unknown age, was dated using dendroarchaeological methods. Located in the Sahtu region of the Northwest Territories' Mackenzie Mountains, on the south side of Stelfox Mountain, the archaeological site is in the traditional territory of the Shúhtag'ine Dene. Dates were obtained for the archaeological wood by pattern matching ring sequences to those of the white spruce (*Picea glauca*) trees surrounding the site. Outcomes provided details regarding the timing of past site use, and a regional chronology extending further back in time than would be possible using only living trees.

2.2 Introduction

Three linear wooden features located on a plateau on the southern side of Stelfox Mountain, identified as caribou fences (GNWT 2016), were constructed by ancestral Shúhtag'ine as part of a complex hunting technology. The “fences” are a long series of detrital boles of trees, overlain end-to-end upon each other, up to a height of ~0.50 m. It is assumed that the wood, of unknown age, used in construction, had been sourced from the locally available white spruce (*Picea glauca*) trees, given that they are the predominant tree species in the study area. The wooden structures were recorded by Government of the Northwest Territories (GNWT) archaeologists in 2009 (GNWT 2016). They have suggested that the fence system was used to guide game animals to a predetermined kill-zone for harvest. This efficient method of hunting required an intimate knowledge of the prey and the land, a ubiquitous trait of hunter-and-gatherers, both past and present (Brink 2008, 2013; Frison 1998; Kendrick 2000; O'Shea et al. 2013, 2014; Parsons 2015; Reeves 1998; Smith 2013; Van Dyke 1975).

For the purposes of this manuscript the features are referred to as major, minor north, and minor south. The major fence, the largest of the three features, is oriented west to east along the high plateau. On the east side of the plateau, it turns and steeply descends into an adjacent valley, where it terminates in a corral-type structure. Presently, the fence and the corral structure are

identified as a single continuous feature. North of the major fence, is minor north, a smaller feature that runs west to east, following a slightly elevated contour across the plateau. The fence to the south has the shortest observable length of the three structures, and is oriented more northwest/southeast than its counterparts. It does descend minimally into the valley at its terminus, but it is difficult to determine whether the remains today are an accurate representation of its original construction extent, or if some portion of the fence fell downslope into the valley near its current terminus.

In an interview with CBC News (2016) Dr. Tom Andrews reported the Moose Horn Pass Caribou Fence as being “at-risk” of being lost. In partnership with the Shúhtagot’ine, a plan was initiated to record the entire site to preserve it as completely as possible in the event it is lost, such as could readily happen if a forest fire sweeps through the area. Obtaining absolute dates for the fence complex is one of the major goals of the total recording process. Obtaining multiple dates for each segment would allow a better understanding of the use-history of the fence complex.

Two pieces of wood, obtained in 2009, were submitted by GNWT officials for radiocarbon dating. The samples yielded calibrated dates of 1660 – 1960 and 1280 – 1400 C.E. (GNWT 2016). Although they had obtained the radiocarbon dates, GNWT archaeologists felt that they were insufficient to produce a detailed assessment of the fences’ use-life. They then sought a more efficient method of dating the fence complex. Because the timbers are generally well preserved, dendroarchaeology was identified as a suitable approach to providing the required information.

Dendroarchaeology is a subfield of dendrochronology, which translates literally as the study of tree time (Fritts 1976; Speer 2010). It is a method of assigning dates to wood-constructed archaeological features and artifacts (Baillie 1982; Douglass 1941; Nash 1999; Speer 2010). It is accomplished by crossdating the observed ring patterns found in archaeological wood to those of the living trees in the region where the wood was obtained. Once accomplished, a calendar year can be assigned to the end-date of the archaeological wood from the pattern derived from the living timeline. Dendroarchaeology therefore has the ability to provide an annual date to the wood, and when appropriate conditions occur, even the season that the wood was obtained

(Fritts 1976). It is this level of accuracy that is required to uncover the history of the Moose Horn Pass Caribou Fence system.

By applying dendroarchaeological methods, this study sought to establish spatial and temporal patterns of use for the three fences. To do so, it was necessary to construct a baseline chronology of the age of living white spruce trees in the Moose Horn Pass region. The longer the chronology that can be built, the greater the number of archaeological samples that will, theoretically, be able to be placed in time. Consequently, temporal patterns may be able to date initial construction and use-history, whether use was continuous or episodic, and when the site was last used or repaired. Spatial patterning to the dates may also indicate areas of concentrated repair and maintenance, or if the fence system had been redesigned or augmented to form its current layout.

The null hypothesis that was tested is that the fences were built at one time, approximately at the time of the Hudson Bay Company meat trade in the region during the late 19th/early 20th centuries. (Andrews 2017). Regardless, this research will provide the project's shareholders, the Shúhtagot'ine and GNWT, a more complete picture of the how and when the site was utilized.

2.3 Study site

Within the Mackenzie Mountains of Canada's Northwest Territories, the Moose Horn Pass Caribou Fence site is located at the base of Stelfox Mountain (63.527777 N, -127.741944 W). The topography is rugged with a change in elevation from valley bottom to summit of Stelfox Mountain being 1270 m (1070 masl – 2340 masl). The region is in the Sahtu Settlement Area, the traditional territory of the Mountain Dené (Shúhtagot'ine). The fence is situated on a plateau, south of two small water bodies, and north of a steep slope descending approximately 48 metres down into an adjacent valley. The valley bottom runs parallel to the plateau and is home to Stelfox Creek between the Moose Horn and Natla Rivers.

Bedrock outcroppings, alluvial fans, and glacial till are found throughout the adjacent alpine environment (Auld and Kershaw 2005). Diamictite, overlain by dolostone, quartz sandstone, and shale are the primary components of the Stelfox Mountain geology (Aitken 1991; Hoffman 2011). The site is not easily accessed and no weather data have been recorded from within the valley. Nearby estimates place its mean annual daily temperature at -6° C, and a

February daily high of -30°C (Auld and Kershaw 2005). The area receives approximately 700 mm of moisture in annual precipitation, most of which falls as snow during the winter months (Auld and Kershaw 2005).

The summer growing season lasts approximately three to five months, with plant communities of the south facing site fairing relatively better than their north facing counterparts. The area's tree community is dominated by white spruce, with some deciduous trees beginning to colonize the lower elevations where ground disturbances appear to have taken place. Wild grasses and forbs are present throughout the site's footprint. Stunted shrubs and bushes are present in the vicinity of the water bodies.

2.4 Methods

2.4.1 Live Tree Sampling

Seventy-five living white spruce trees from within the site area were sampled at 1.3 m from the ground, and two cores were taken from each tree ($n=150$ cores). Increment cores were obtained from trees selected from areas adjacent to the archaeological site (Figure 2. 1) using standard 5.1mm increment borers (Figure C. 3). Two samples were taken to help eliminate expected aberrations in the ring patterns arising from the effects of harsh growing conditions. In flat areas, cores were taken at 90° from each other, and on slopes they were taken at 180° from one another, perpendicular to the direction of the slope. Cores were transferred to plastic drinking straws, sealed, labeled sequentially, and returned to the laboratory for processing. Cores from living trees are important as the year that they were cored provides the anchor in time necessary for the chronology to extend back in time. The pattern of the individual cores would eventually be averaged to determine the site's overall master chronology of growing conditions.

2.4.2 Standing Dead Wood

Twenty-one standing-dead trees (snags) were cored to assist in potentially extending the 'living' chronology further back in time. In harsh mountain environments, it has been illustrated that standing snags can remain stuck in time with little to no degradation to the wood (e.g., Kellner et al. 2000). If this also occurred at the study site, then standing snags might be able

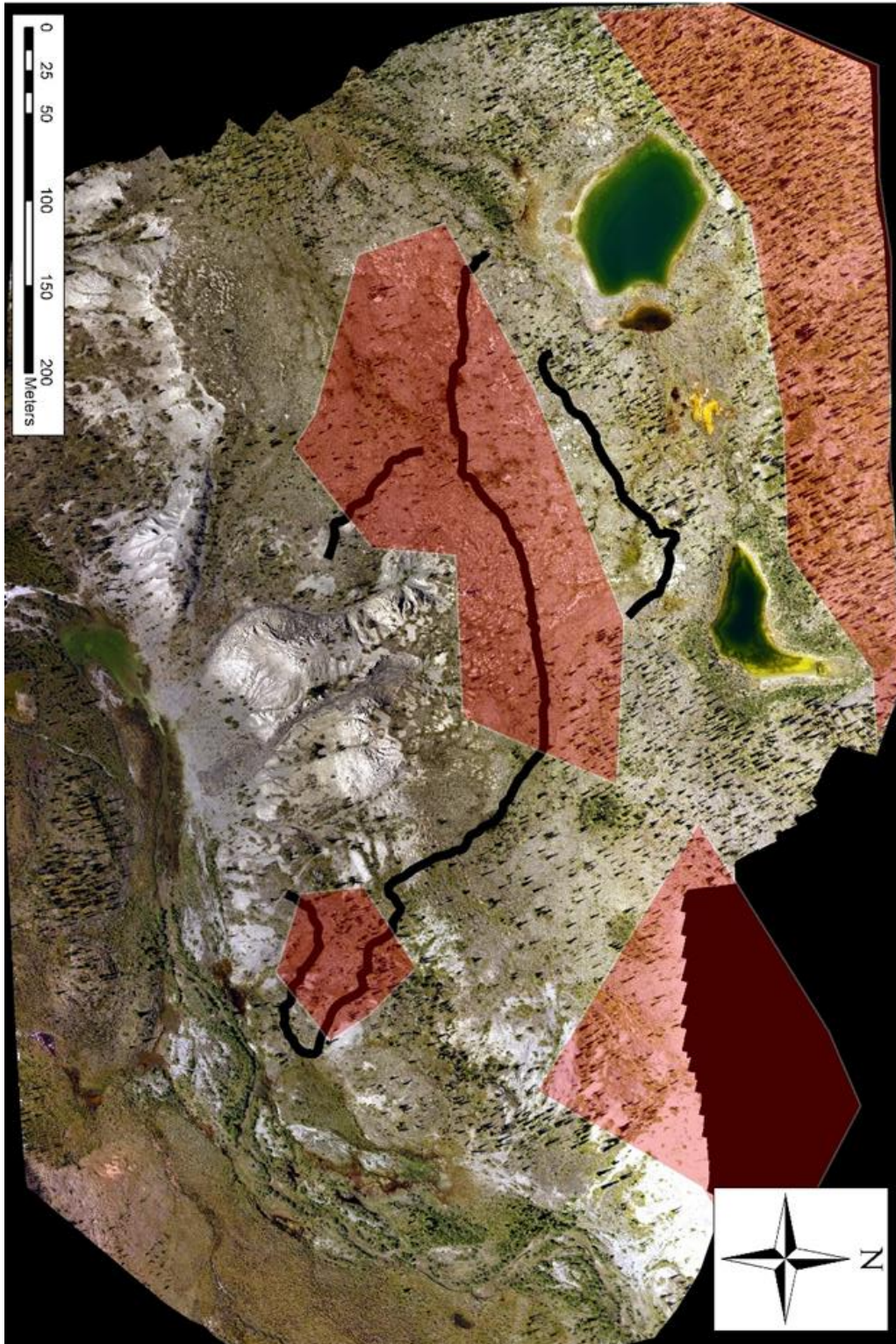


Figure 2. 1 - Coring zones indicated by red shading.

to be pattern matched into the existing living chronology and push the “anchored in time” chronology back further. An extended chronology would greatly assist bridging the presumed time gap between the anchored chronology and any very old archaeological wood from the fence system.

Snags were sampled in much the same way as the living trees. In the 2016 field season, they were selected and sampled as they were encountered during live-tree sampling. An exception occurred during the second (2017) field season when, due to time limitations, 15 standing-dead trees were obtained by coring entirely through the tree.

2.4.3 Archaeological Samples

Archaeological wood from throughout the fence system was also obtained (Figure 2. 2). A walk-through survey of each of the three fences was conducted, and solid contiguous pieces of tree boles were highlighted as potential sampling locations. Duct tape was wrapped on logs at approximately 1.3 m from the root collar of the tree to mimic the sampling height of the live samples. An approximate 12 cm section was then cut out of the longer log with a chainsaw, and then rewrapped in plastic shipping wrap for transportation back to the lab for processing. In total, 84 samples were collected across the three fences. The individual cross-sections from the 84 samples each provided a “floating chronology”, one whose rings are not yet assigned to any known calendar years. Once an archaeological sample’s floating measurement pattern was found and placed in time through comparison to the living/snag (master) chronology, the sequence was added to that chronology, adding sample depth to the master, as well as pushing the anchored window further back in time.

Added to the archaeological cross-sections were five pieces cut from standing-dead trees. The trees had been axe-cut, and although it is very possible that they represent timbers included in the fences’ construction, it cannot be stated absolutely. They were, for all intents and purposes, considered to be snags.

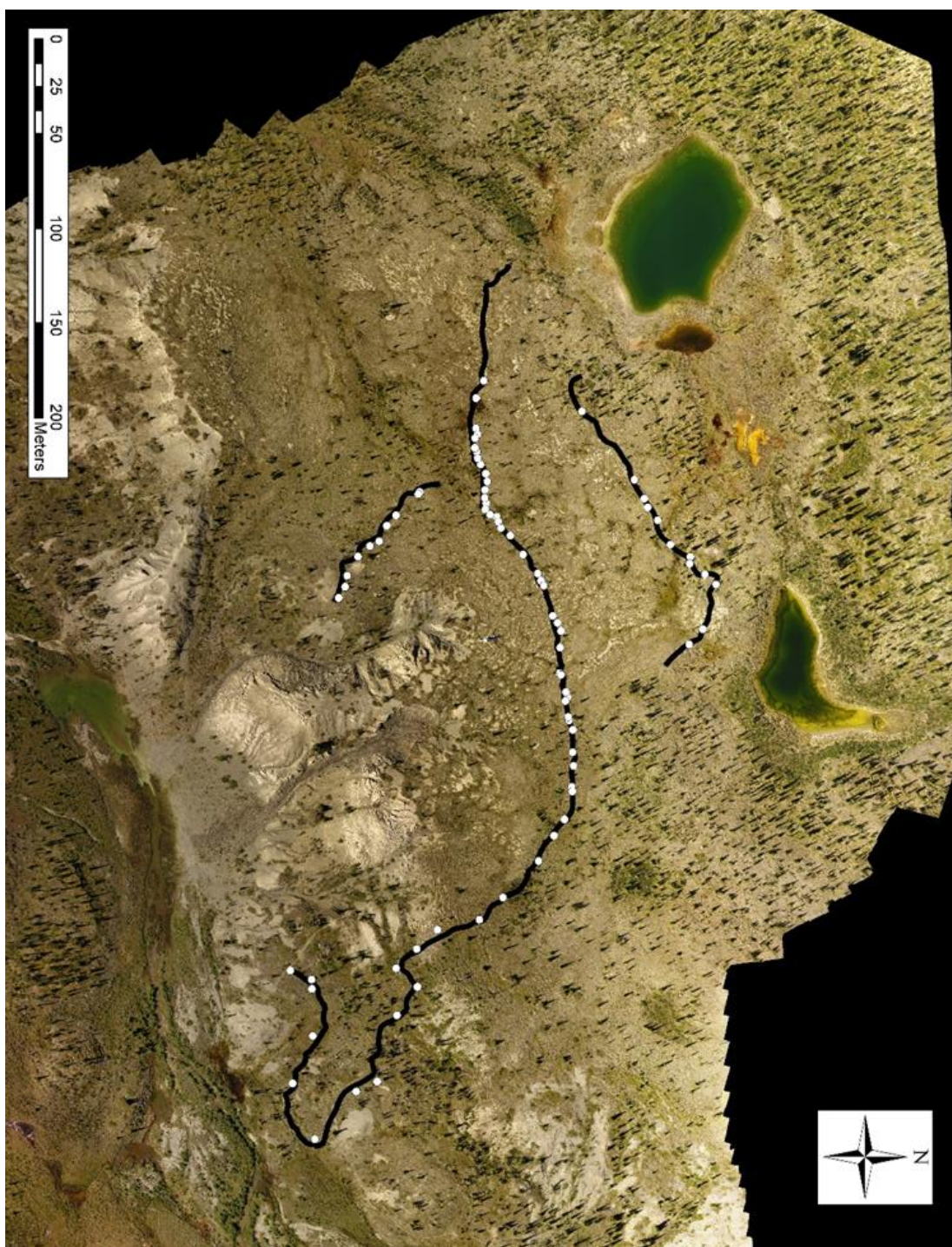


Figure 2. 2 - Locations of archaeological cross-sections cut from the three fences.

2.4.4 Laboratory Preparation Cores

Initial preparation differs between the cores and cross-sections. Increment cores from each tree were glued parallel to each other in grooved mounting boards (Figure C. 4). Their labels from the field were written on the boards to ensure consistency in identification for each sample in the study. The mounting boards are ideally suited to provide a stable base during the measurement procedure, as well as being a secure, and efficient method of storage after completion of the lab analysis.

2.4.5 Laboratory Preparation Cross-Sections

Cross-sections were cut to a width of approximately 5 cm using a band-saw. Width varied when the wood's physical structure made it impractical, or unsafe, to cut at the preferred thickness. Basic steps were taken to ensure cross-section integrity of the wide variation of wood quality brought back to the lab. For most solid pieces, simply wrapping them several times with duct tape was sufficient. In cases where material loss and wood damage were evident, but not severe, wood glue was added in stages over several days to solidify those sections that appeared most at risk to deformation or degradation. This was in addition to the duct tape wrap. In a few instances, standard processes would not provide the necessary degree of structural integrity required for further processing. In these cases, steps were developed and applied experimentally with low-expansion foam, prior to cutting (see Appendix A). In the end, of the 84 archaeological samples taken from the field, only two were deemed unsuitable for processing because of the poor physical condition of the wood.

2.4.6 Sanding

Both cores and cross-sections were sanded using an up to ten-step process. The environment at Stelfox Mountain is such that trees tend to grow very little each year. This results in very fine rings with boundaries that are difficult to determine without a highly-polished surface. In general, conifers grown in an environment more conducive to wider rings require a six-stage process using progressively finer sandpaper with a range of 80-600 grit paper to fully illustrate their cellular structures. This standard MAD Lab protocol usually provides sufficient visibility for rings to be seen and accurate measurements to be taken. In this study, additional sanding was required for both the cores, and the cross-sections. This was performed using grits from 600-1200, followed by mechanical buffing.

2.4.7 Measurement

Using a Velmex stage system (Figure C. 5) ring widths were measured to 0.001 mm and recorded using J2X software (Voortech 2014). Two records were generated for each tree and snag, an “A” and “B” sequence representing the two cores taken from each tree. Archaeological cross-sections were marked with an A and B path to indicate areas with the greatest number of rings present. This procedure was conducted to maintain consistency between the sample types.

2.4.8 Crossdating Analysis

The recorded living, snag, and archaeological sequences were crossdated using both visual and computer assisted methods in order to determine the archaeological end-dates.

2.4.8.1 Living and Snag Samples

Using COFECHA (Grissino-Mayer 2001, Holmes 1983), signal homogeneity of the living and snag tree measurements were checked. Potential problems reported by COFECHA were addressed on a case-by-case basis. The problematic series would either be remeasured, or visually crossdated to determine the source of the problem. In both cases, a new iteration of a COFECHA analysis would be run. The initial master chronology, representative of only the living trees, was constructed once all problems were accounted for, and the reported inter-correlation value of the chronology exceeded the critical correlation level of 0.3281 for 50-year segments, required for the 99% confidence interval (for discussion, see Grissino-Mayer 2001). Afterwards, snag samples were added one at a time and initial placement was suggested by program COFECHA, and then visually checked for a robust pattern match to the living chronology.

2.4.8.2 Archaeological Samples

The two sequences of ring measurements recorded for the individual archaeological samples were first compared against each other prior to any attempted crossdating. The goal of this step was to eliminate the uncertainty resulting from two paths of potentially unequal ages exhibiting high and/or low crossdating potential relative to each other. It was felt that an agreement between the floating A and B series’ for one sample would result in more robust statistical results when crossdated to the master chronology. In this way, the two paths of each individual sample were averaged into their own unique floating chronology, and then the two paths were compared against the master chronology. Once those individuals with the most recent

end-dates were found and added into the master chronology, progressively older series of archaeological samples were crossdated and added into the master. The obtained dates provided insights into the use-life and construction dates of the fence complex.

2.4.8.3 Master Chronology

In summary, the master chronology, which began as representative of the living trees, was therefore extended further back in time as snags and archaeological wood were added. As the archaeological content of the master chronology increased, more, and older, archaeological wood was added. The final master chronology is comprised of living, standing dead, and archaeological ring patterns of a time length and a sample depth not possible using living trees alone.

2.5 Results

The final Stelfox Mountain master chronology covers the calendar years from 972 to 2016 C.E. inclusive (Figure 2. 3). COFECHA reported a series intercorrelation for the overall master chronology of 0.562, well above the critical correlation target of 0.3281. Flags were present in 116 (5.4%) of the 2146 segments. Of those flags, 51 were positioned “highest as dated”, and 35 indicated an increased correlation value of no more than .05 if moved within the - 10 - +10 window. Five of the remaining flags had a correlation value greater than 0.3281, leaving 25 flags representing potential problems in 1.2% of the chronology’s analyzed segments (Table D. 1). This demonstrates that although individual responses to environmental conditions varied widely, the community at large shared strong tendencies throughout time.

2.5.1 Living Trees

Ranging in age from 49 to 376 years old, 74 living trees from zones around the fences are in the final master chronology. Trees sampled north of the fences proved to be oldest, while those from the plateau proved to be much younger (Table D. 2).

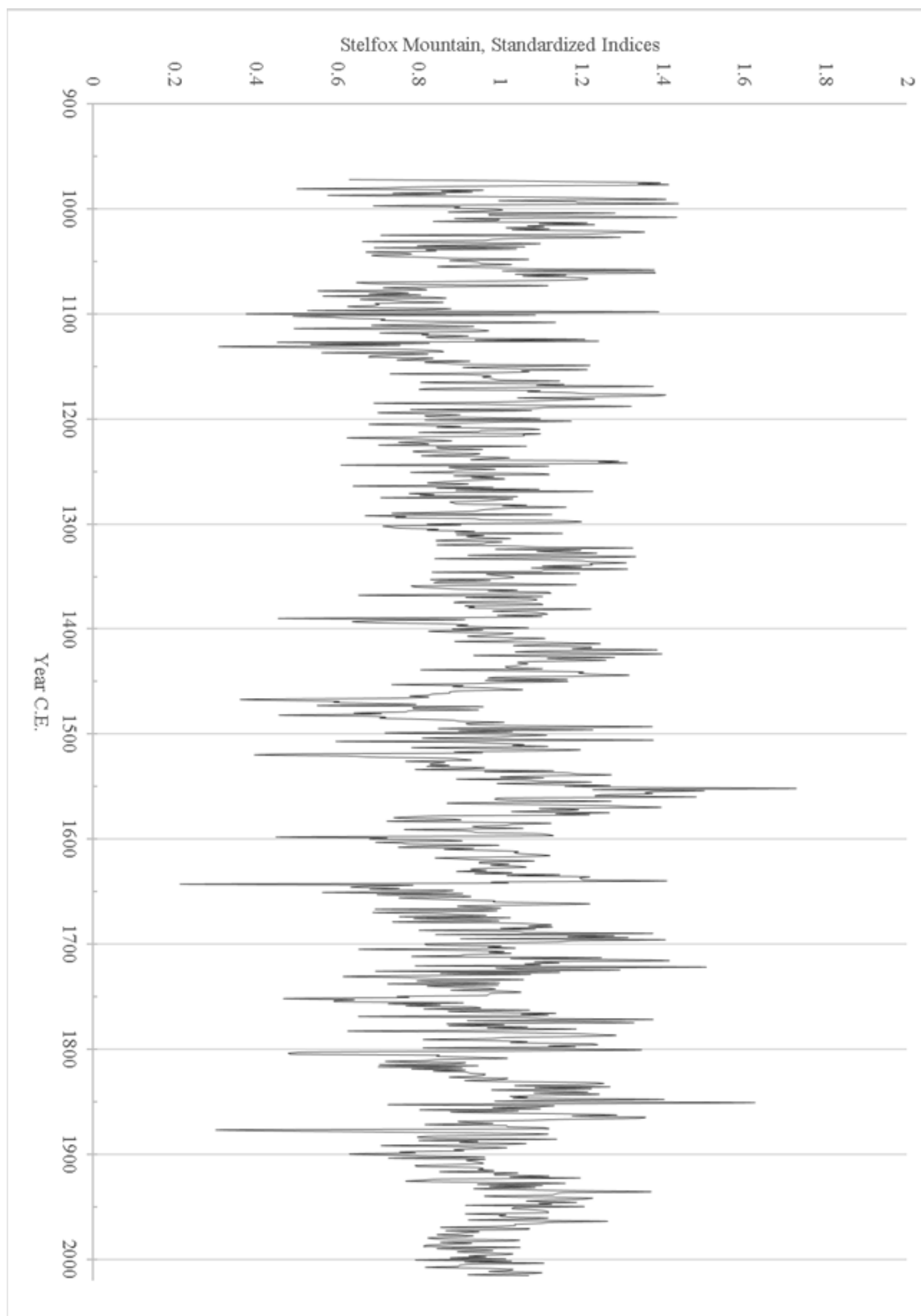


Figure 2. 3 - Graph of final Stelfox Mountain standardized master chronology, where 1.0 is average, and values +/- 1.0 represent wider and narrower rings.

2.5.2 Snags

Twenty-four snags were included in the final chronology. Three had end-dates in the 1900s, while the oldest was crossdated into the master chronology between 1149 and 1450 C.E. The snags' contribution to the final sample depth of the site's master chronology was especially evident between 1850 and 1750 C.E. During that period, the number of living trees samples was steadily decreasing, and the archaeological wood was not yet substantially present in the site chronology (Figure 2. 4). At 1750 C.E., living trees were only contributing 10 series to the sample depth of the master chronology, while minimal archaeological wood had yet to be matched into the living chronology. The inclusion of snags in the site chronology served to almost double the combined contribution of archaeological and living series over this specific time period (Figure 2. 5).

2.5.3 Archaeological Wood

At its completion, 62 of the 84 archaeological cross-sections were successfully placed within the site's master chronology (Table 2. 1). The average end date was found to be 1620 C.E., with the mean of measured rings per cross-section being 214. Two date clusters represent the majority of archaeological end dates: 1420-1480 and 1580-1750 CE (Figure 2. 6). Only two end dates represented 19th century calendar years (1876, major fence, 16LD059 and 1843, north fence, 16LD010).

The inclusion of archaeological wood in the chronology was, for the most part, restricted to those series whose correlation scores were well above the 99% critical threshold (0.3281). Of the 124 series representing the 62 archaeological cross-sections included in the site's final master chronology, only one series was below 0.400, but at 0.388 was still greater than required for the 99% confidence interval. Nineteen fell between 0.400 and 0.499, while the remaining 104 series were >0.500 . The series with the lowest correlation scores were included because visual crossdating confirmed their fit. Any series scoring <0.500 that could not be accurately crossdated visually were not added to the master chronology.

The entire measurement patterns of 62 of the cross-sections were able to be placed into the master chronology with a robust fit, but 19 of the samples only fit partially. End dates for the 19 were determined by crossdating, but these measurement patterns were not added to the overall

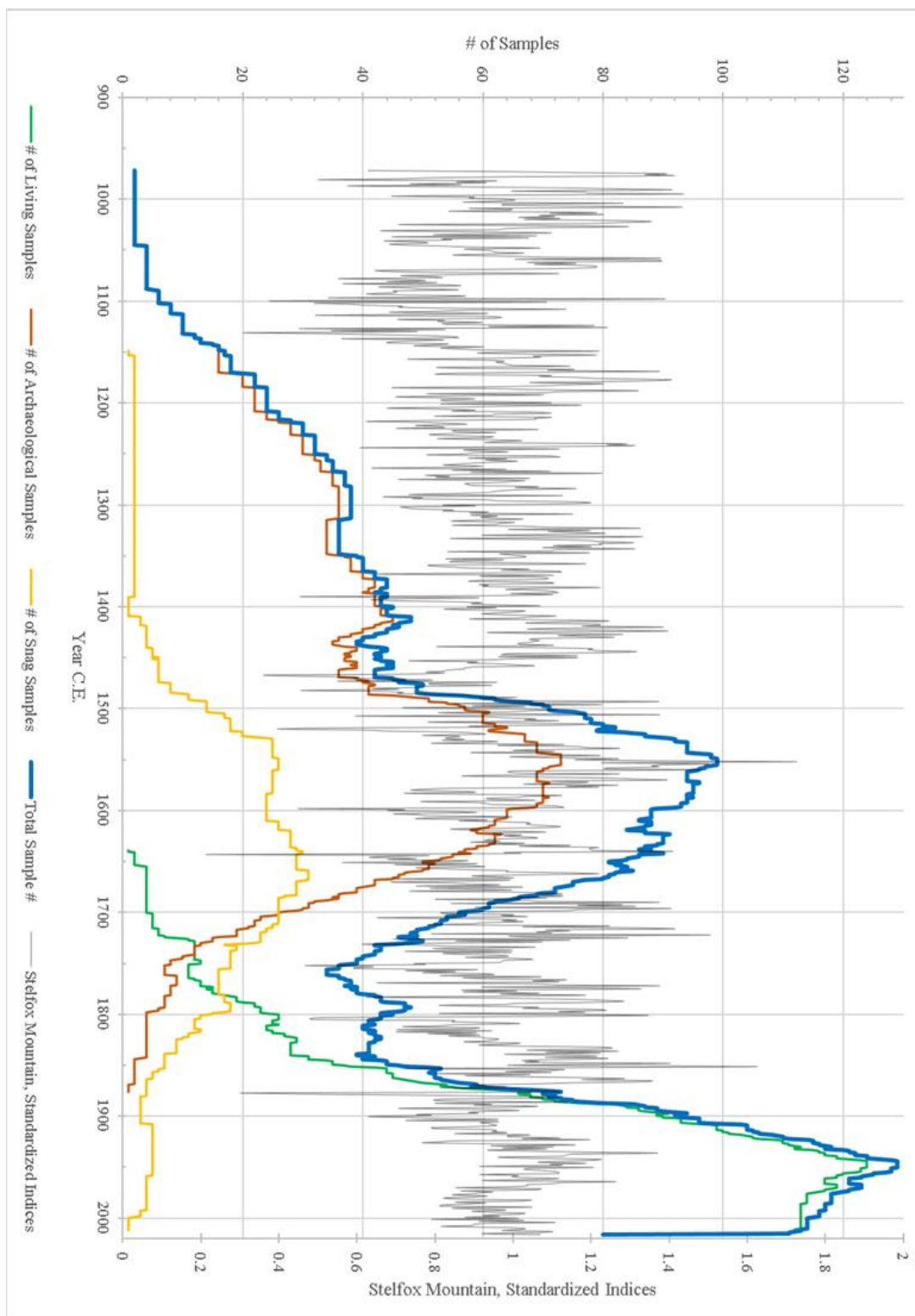


Figure 2. 4 - Bridging effect of snag wood to overall sample size of the chronology.

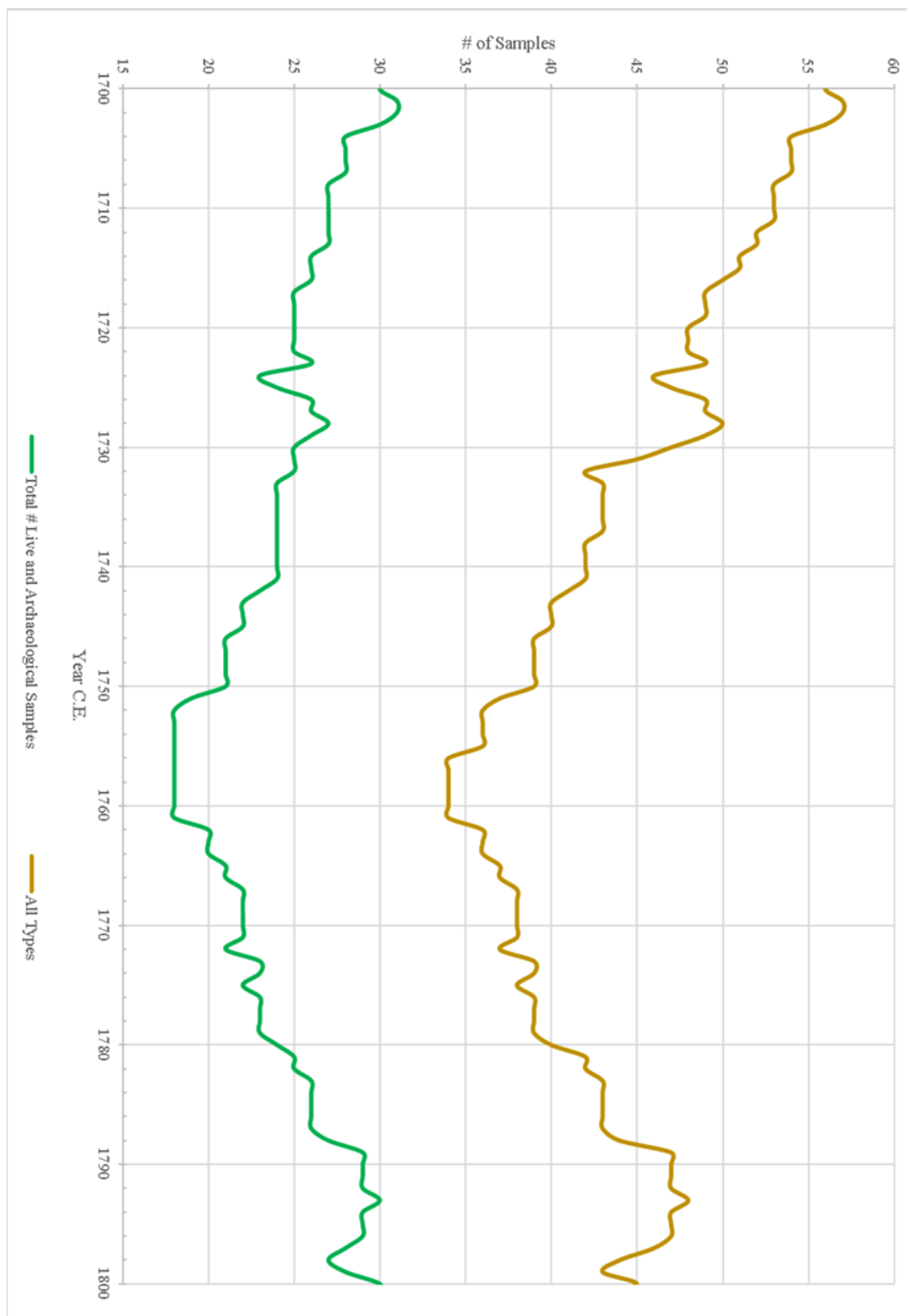


Figure 2. 5 - Snags double the sample depth during a dramatic drop in sample size extending back to mid-18th century.

2016: 16LD001 - 16LD070													2017: 17KL001 - 17KL014				
MAJOR 31/47				NORTH 10/13				SOUTH 8/10				CORRAL 13/14					
CUT	FYOG	END DATE	YEARS	CUT	FYOG	END DATE	YEARS	CUT	FYOG	END DATE	YEARS	CUT	FYOG	END DATE	YEARS		
31	25	1138	1460	327	1	1450	1681	191	14	1623	1746	1	1470	1684	214		
	26	1489	1723	234	2	1366	1520	154	15	1488	1707	2	1587	1675	88		
	30	1496	1687	191	3	1108	1598	435	16	1046	1477	3	1572	1713	141		
	32	1172	1556	384	4	1113	1385	272	18	1373	1597	5	1642	1797	155		
	33	1487	1724	237	6	1448	1646	198	19	1251	1460	6	1686	1793	107		
	35	1609	1723	114	8	1523	1649	126	20	972	1314	7	1350	1623	273		
	37	1217	1457	240	10	1762	1843	81	22	1652	1732	8	1538	1703	170		
	40	1257	1637	380	11	1232	1426	194	23	1400	1561	9	1458	1686	228		
	41	1137	1447	310	12	1089	1438	349	AVERAGE		1351	1574	1667	164			
	42	1544	1715	171	13	1220	1433	213	MEDIAN		1387	1579	214				
	45	1171	1421	250	AVERAGE		1335	1562	227	MAXIMUM		1652	1746	431			
	47	1268	1519	251	MEDIAN		1299	1559	196	MINIMUM		972	1314	80			
	48	1349	1771	422	MAXIMUM		1762	1843	455	ADJ. AVG. *		1364	1589	213			
	49	1142	1461	319	MINIMUM		1089	1385	81	ADJ. AVG. *		1530	1698	163			
	52	1185	1429	244	ADJ. AVG. *		1312	1549	212	AVERAGE		1528	1700	172			
	70	1515	1617	102	MEDIAN		1524	1688	164	MAXIMUM		1686	1797	273			
	53	1475	1699	224	MAXIMUM		1686	1797	273	MINIMUM		1350	1623	88			
	54	1387	1597	210	ADJ. AVG. *		1530	1698	171	ADJ. AVG. *		1530	1698	171			
	56	1439	1634	195	AVERAGE		1406	1620	212	MEDIAN		1464	1642	204			
	57	1472	1596	124	MEDIAN		1464	1642	204	MAXIMUM		1762	1876	455			
	58	1454	1619	165	MAXIMUM		1762	1876	455	MINIMUM		972	1314	80			
	59	1623	1876	253	MINIMUM		972	1314	80	ADJ. AVG. *		1407	1621	263			
	60	1209	1437	228	ADJ. AVG. *		1407	1621	263	ADJ. AVG. *		1407	1621	263			
	61	1438	1642	204	ALL FENCE		FYOG		END DATE YEARS	62/84		ADJ. AVG. *		1407	1621	263	
	62	1502	1610	108	AVERAGE		1406	1620	212	ADJ. AVG. *		ADJ. AVG. *		1407	1621	263	
	63	1440	1642	202	MEDIAN		1464	1642	204	ADJ. AVG. *		ADJ. AVG. *		1407	1621	263	
	65	1470	1703	233	MAXIMUM		1762	1876	455	ADJ. AVG. *		ADJ. AVG. *		1407	1621	263	
	66	1487	1660	173	MINIMUM		972	1314	80	ADJ. AVG. *		ADJ. AVG. *		1407	1621	263	
	67	1620	1741	121	ADJ. AVG. *		1407	1621	263	ADJ. AVG. *		ADJ. AVG. *		1407	1621	263	
	68	1409	1640	231	ADJ. AVG. *		1407	1621	263	ADJ. AVG. *		ADJ. AVG. *		1407	1621	263	
	69	1545	1665	120	ADJ. AVG. *		1407	1621	263	ADJ. AVG. *		ADJ. AVG. *		1407	1621	263	
AVERAGE	1392	1616	225														
MEDIAN	1440	1637	228														
MAXIMUM	1623	1876	422														
MINIMUM	1133	1421	102														
ADJ. AVG. *	1398	1614	222														

* Adjusted Average (ADJ. AVG.) excludes maximum and minimum values from calculations.

FY- AVG	FY- MED	FY- MAX	FY- MIN	ED- AVG	ED- MED	ED- MAX	ED- MIN	FY ADJ. AVG. *	ED ADJ. AVG. *	YRS- AVG	YRS- MED	YRS- MAX	YRS- MIN	ADJ. AVG. *
Major	1392	1440	1623	1133	1616	1637	1876	1421	1393	225	228	422	102	222
North	1335	1299	1762	1089	1562	1559	1843	1385	1312	227	196	435	81	212
South	1351	1387	1652	972	1574	1746	1314	1364	1589	224	214	431	80	213
Corral	1528	1524	1686	1350	1700	1688	1797	1623	1530	172	164	273	88	171
Fence All	1406	1464	1762	972	1620	1642	1876	1314	1407	212	204	435	80	263

ALL FENCE	FYOG	END DATE YEARS	62/84
AVERAGE	1406	1620	212
MEDIAN	1464	1642	204
MAXIMUM	1762	1876	455
MINIMUM	972	1314	80
ADJ. AVG. *	1407	1621	263

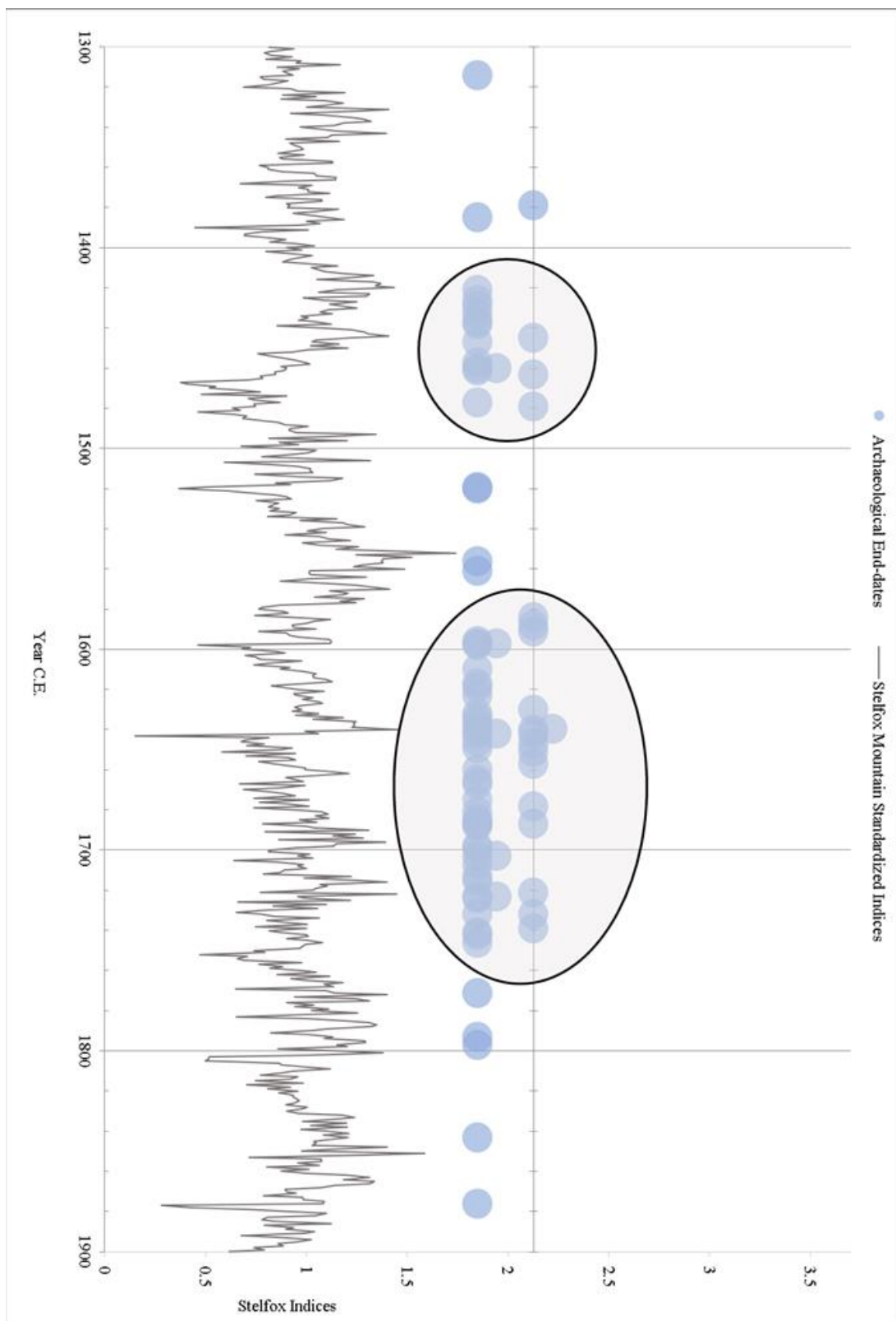


Figure 2. 6 - Archaeological end-date clusters plotted against the Stelfox Mountain master chronology.

master chronology. For example, some of these cross-sections had portions of their sequences in their early years that did not crossdate well, often because of localized rot, missing rings, reaction wood, or a combination of other growth aberrations. Since the entire measurement sequence could not be matched with confidence, all of the data did not make the master chronology. The data provided by their end-dates were still very valuable though, and so they were still included in the final analysis of the spatial and temporal date clusters attributed to the individual fences.

2.6 Discussion

In the early stages of the chronology's development, six time periods provided significant obstacles (Table D. 3). The period between 1799 and 1805 C.E. was particularly problematic as a result of an extreme frost event (1799), which was evident in almost every core, followed by a period of extremely limited growth (1803 – 1805 inclusive). The growth between 1803 and 1805 was so stunted that the majority of trees exhibited at least one absent ring between their two cores; in many cases an entire year was missing, and in one instance all three years were missing. These factors threatened to prevent extension of the chronology into the 18th century. Repeated graphing and statistical analysis provided no conclusive indication of the actual sequence.

High resolution scanning was employed to attempt various methods of visual crossdating. Cores with uninterrupted sequences and matching marker rings on either side of the damage were required to bridge and eventually understand what happened in the affected years. Several cores were found to be free of a break in their sequences, and shared the marker rings (1904, 1877, 1850, 1819, 1817, 1783, 1773, 1769 C.E.), on either side of the disturbance. Crossdating these specific marker rings allowed for the site's chronology to extend back into the 18th century.

A method of comparing the Stelfox chronology against comparative chronologies was sought to verify the chronology's accuracy. The International Tree-Ring Data Bank (ITRDB) indicates that the two closest studies (Chapter 1, Figure 1. 9) derive from the periphery of the Mackenzie Mountains (Jacoby et al. 2005; Sauchyn 2008). These were the basis of comparison because analogous chronologies within close proximity to Stelfox Mountain are not available. Their raw data was standardized and plotted against the Stelfox chronology (Figure 2. 7 and Figure 2. 8) to determine if a general pattern of growth was shared between the three chronologies. The comparative data did indicate similar trends over the course of their overlap.

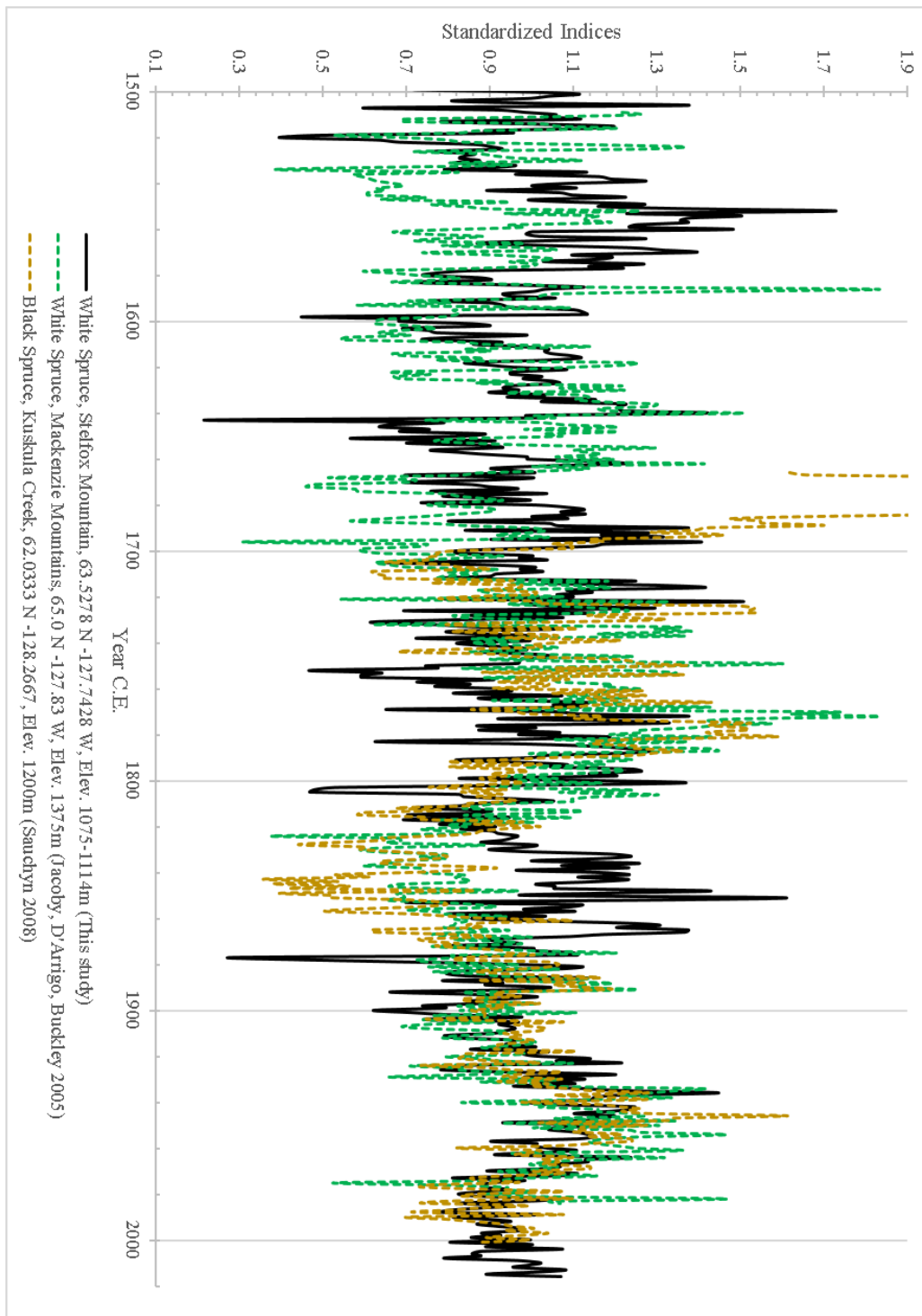


Figure 2. 7 - Comparison of Stelfox Mountain, Mackenzie Mountains, and Kuskula Creek chronologies over their shared time periods.



It was expected that differences in individual years would be present between the three chronologies, but that the general pattern would be consistent between them. The only apparent difference, discussed below, was between 1820 and 1870 C.E. There was a noticeable decrease in the sample sizes of living trees from all three sites during the 1650 – 1750 C.E. time period, indicating a shared set of difficult growing conditions (Figure 2. 9). It is after this decrease in the sample size of the living trees that the archaeological wood sample size from the fences substantially increases. It may at some point be worth exploring why this gap between the decrease in living and increase in archaeological wood exists. A significant period of poor growing conditions exists ~1700 C.E., and therefore overall growing conditions and a widespread death of trees may be related to the drop in sample size.

A divergence in growth indices between the Stelfox Mountain trees and the comparison sites from 1820-1870 C.E. (Figure 2. 10) indicates a period of better growing conditions within the mountains relative to those experienced at the margins. These conditions presumably impacted other tree and plant communities in much the same way as with the measured white spruce trees. A positive growing environment for the entire ecosystem would in turn serve to pull grazing animals into the region for longer periods of time (Bowyer 2011). The implied increase in food supply would result in an increased carrying capacity for caribou, and presumably, an increased population. This equates to a potential increase in successful hunts in the mid to late 19th century when climatic conditions were coming out of the Little Ice Age.

With an apparent agreement between the three sequences, it is reasonable to state that methods employed to circumvent problematic years in this study were successful, and that the Stelfox chronology was accurate and suitable for dating the older archaeological material.

2.7 Conclusion

Stelfox Mountain has been home to a well-populated coniferous forest for close to a millennium. Because of the extremely slow processes of decay in this harsh environment, living trees, snags, and 81 cross-sections taken from the archaeological remains of the Moose Horn Caribou Fence, together built over a one-thousand year long chronology (972 to 2016 CE).

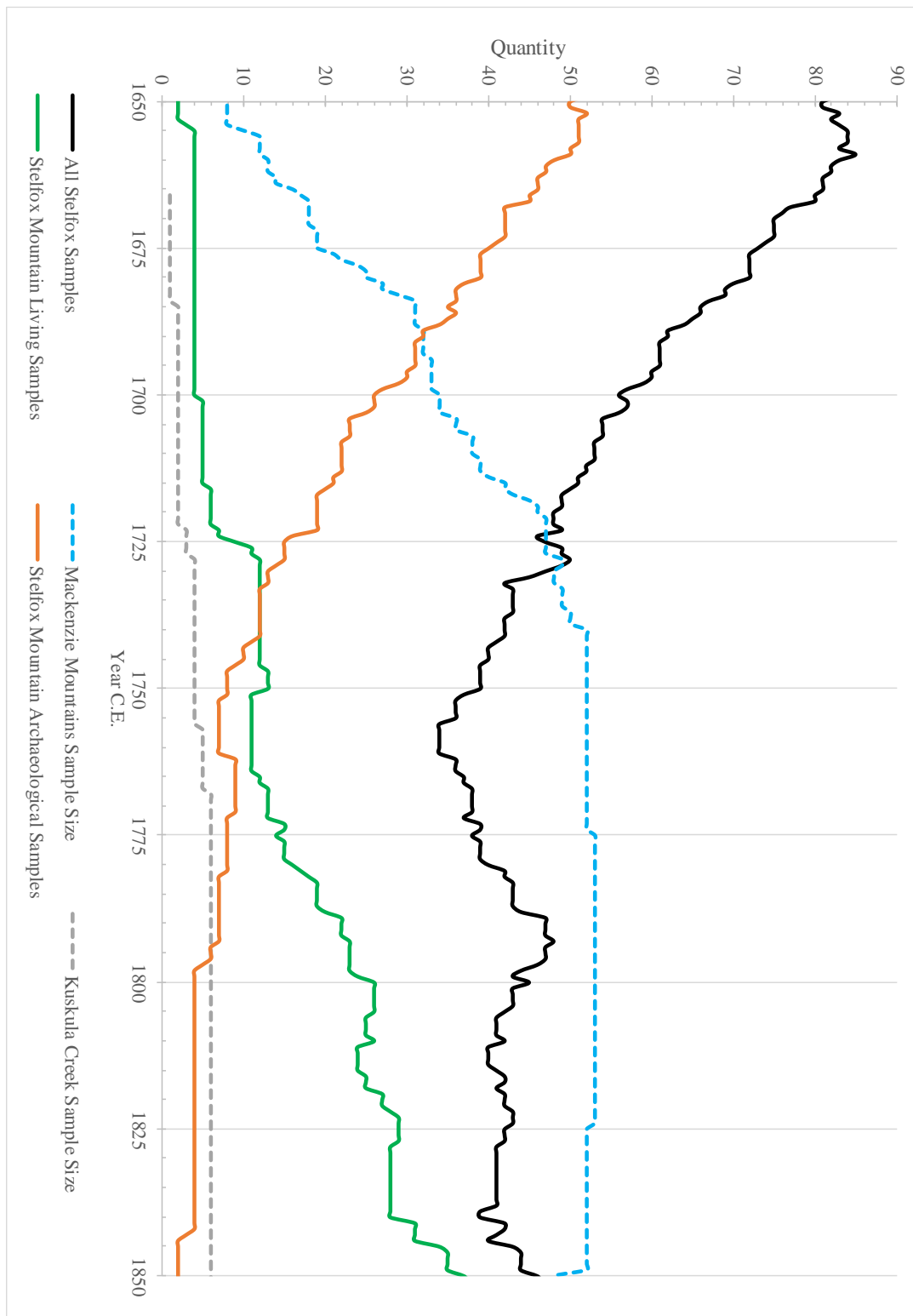


Figure 2. 9 - Decrease in Stelfox Mountain, Mackenzie Mountains, and Kuskula Creek living tree sample size c.1750 and the increase in archaeological wood extending back in time.

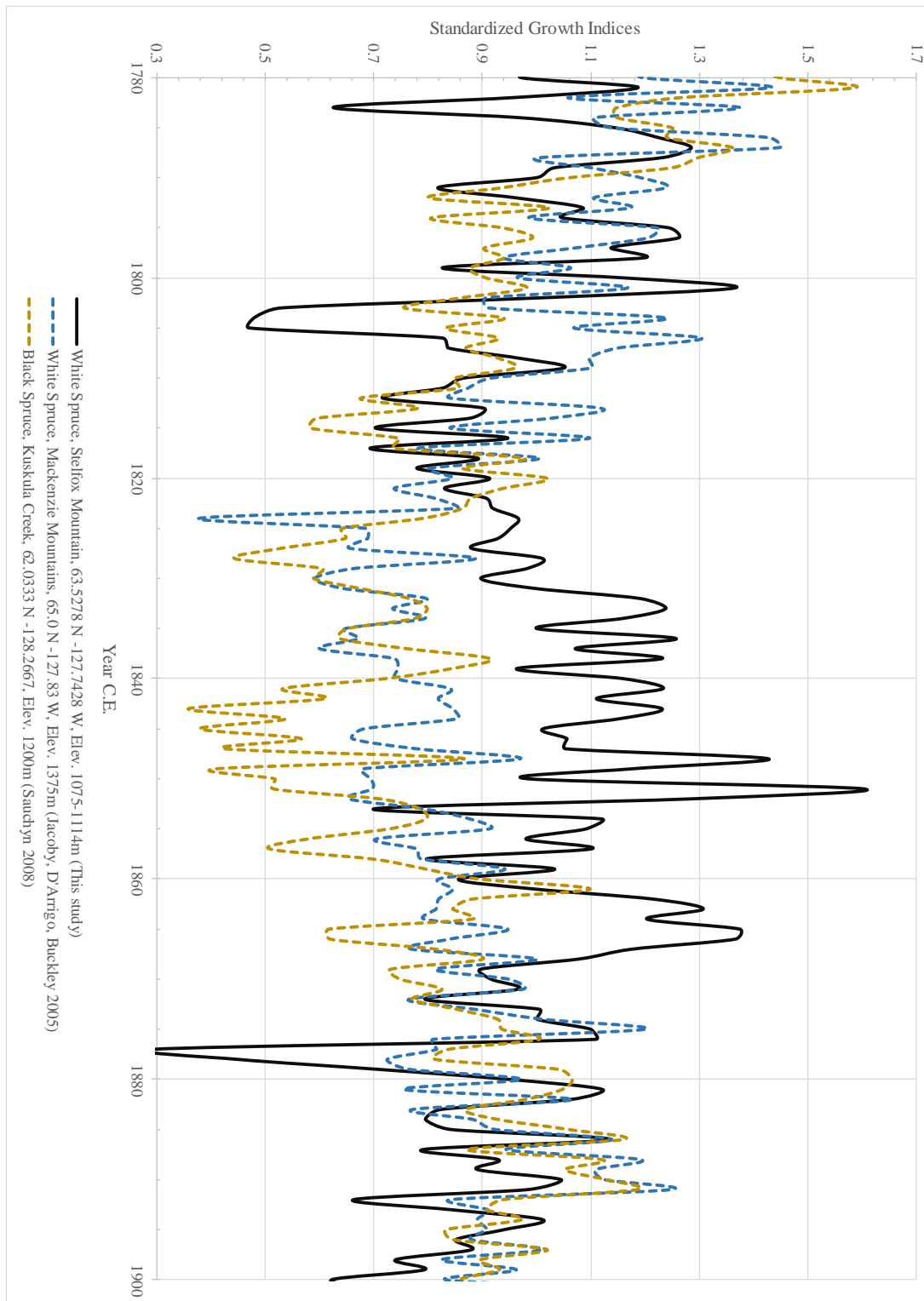


Figure 2. 10 - Stelfox Mountain divergence from Mackenzie Mountains, and Kuskula Creek chronologies in 19th century.

The chronology is the first of its kind for both archaeology and dendrochronology studies in the region. It is the first chronology developed using dendroarchaeological methods on such a large scale in the subarctic, and it is the first to be produced from a study site located deep within the Mackenzie Mountains.

The successful crossdating of 81 pieces of archaeological wood reveals date clusters, 1421-1477 and 1597-1746 C.E. (Figure 2. 6), that imply discrete periods of site construction and use. The dates, considerably earlier than originally hypothesized, indicate that ancestral Shúhtagot'ine had used the site, discontinuously, for centuries. The extended chronology can now be used as a base for further dendroarchaeological studies within the region, and on other important cultural artifacts important to the Shúhtagot'ine within their traditional area.

The threat of fire, or other events, caused by warming, is a recognized danger to the archaeological resources of the site. If these events come to pass, it will be a significant cultural and scientific loss. Thus, even though the current project resulted in damage to the fences, the chronology itself also has been identified as having the potential to combine with Shúhtagot'ine Traditional Knowledge (TK) to expand the understanding of the site and the region. Bringing the empirical and cultural aspects together, to the benefit of both, presents a unique opportunity to explore the past changing land uses within this dynamic environment.

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3.0 Title of Manuscript: Applying UAV Obtained Multispectral Data and Dendroarchaeology to Gain Insights Regarding the Use History of the Moose Horn Pass Caribou Fence

3.1 Abstract

The Sahtu region of the Northwest Territories, the traditional territory of the Shúhtagot'ine Dene, is home to a large and complex archaeological site. The Moose Horn Pass Caribou Fence (KjRx-1) is a communal kill site on the south side of Stelfox Mountain, deep within the Mackenzie Mountain range. The site consists of three fences, constructed and used by past hunters to manipulate the movements of local game animals in order to steer them to predetermined kill-zones for harvest.

Supported by unmanned air vehicle (UAV) obtained data, 81 archaeological end-dates obtained during this study's dendroarchaeological assessment of the Moose Horn Pass Caribou Fence, were mapped and evaluated based on their relationships to each other, and to the physical conditions of their immediate environment. The dates, spanning the calendar years 1314 – 1876, and remotely sensed data, provided insights regarding how the fence complex functioned as a hunting tool, and the timing of its use.

3.2 Introduction

Deep in the Mackenzie Mountains of the Northwest Territories, one of the best preserved caribou fences in the world sits waiting to tell a story. In 2009 Government of the Northwest Territories (GNWT) scientists assessed the site (Andrews et al. 2016, GNWT 2016). Territorial archaeologist, Dr. Tom Andrews, in an interview with CBC News (2016) expressed concern that the large wooden fence complex would someday be lost to the increased incidences of forest fires in the region. There was concern that if a fire ever did enter the valley, all of the use history of the site and much of its Indigenous roots would be lost.

In the spring of 2016 they decided a more thorough recording of the site was required. In collaboration with the Shúhtagot'ine [Mountain Dene] First Peoples, they evaluated all of the

methodologies that they could use to get a more holistic picture of what happened at the site in the past, and perhaps more importantly, when the bulk of the activities at the site had occurred. After evaluating several research possibilities, they decided that a dendroarchaeological project would prove a valuable tool for documenting the use history of the caribou fence.

Dendroarchaeology is the study of dating archaeological artifacts by using the science of tree-ring analysis (Kaennel and Schweingruber 1995). In a dendroarchaeological assessment of the caribou fences, samples would be collected from live trees growing near the caribou fence and a tree-ring pattern of annual growth increments would be constructed for all years going back in time to when the trees began to grow. The year in which the trees were sampled provides an anchor in time, and each successive year moving back in time could therefore be assigned to a particular calendar year. Then pieces from the caribou fence could be sampled, and once a pattern for each log was obtained, a pattern matching exercise could be completed to overlap the patterns of unknown age from the fence into the pattern of live trees. In this way, dates of use history could be established not just for one or two pieces of wood from the fence, but for many. This information would have the benefit of better establishing a comprehensive picture of the use history of the entire site, including capturing chronological variation if different parts of the fence complex had been constructed, used and repaired at different points in time.

In conjunction with the dendroarchaeological project, an unmanned air vehicle (UAV) was able to fly small sensor arrays over the site, and in a short time, gigabytes of information were obtained using both visual and other light bands (wavelengths). Laboratory analysis of the resulting data revealed aspects of the site not visible to the human eye alone. The process of photographing the study site in high resolution from the air also has the benefit of allowing every object at the site to be placed in space. When this is combined with the temporal information available from the dendroarchaeological study, a detailed use history of the archaeological site can be gleaned.

3.2.1 Main Objective

Although hypotheses have been advanced, little is actually known about the fence complex. GNWT archeologists hypothesized that the fences were used at the beginning of the 1900s to facilitate and increase the caribou harvest associated with the historic NWT meat trade (Andrews et al. 2012; Sahtu Heritage Places and Sites Joint Working Group 2000). A

complementary hypothesis advanced by Shúhtagot'ine elders (Leon Andrew, personal communication 2018), but with different implications, is that although the fence systems were used during the historic meat trade, oral history suggests that the fence system had been employed much earlier. Thus, the main objective of this research is to better understand the use history of the Moose Horn Pass caribou fence. If the fence predates the historic meat-trade then it is expected that a pattern would emerge indicating fence building activity proceeding the mid-19th century. Regardless, a determination of attributes found on the landscape available through the UAV research may serve to complement the conclusions drawn from the dendroarchaeological data.

3.3 Study Site

The Moose Horn Pass Caribou Fence site is located on the south side of Stelfox Mountain in the Northwest Territories' Mackenzie Mountains. It is deep within traditional Shúhtagot'ine territory, and directly on one of the many traditional Shúhtagot'ine trails located within the territory (Sahtu Land Use Planning Board 2011). It also falls within the migratory range of the Redstone Caribou Herd, a vital part of the traditional Shúhtagot'ine subsistence economy (Figure 3. 1).

The fence system consists of at least three individual fences. The largest fence runs through the middle of a plateau, and then drops over a steep decline toward Stelfox Creek, adjacent to the plateau. This major fence runs down the slope and continues in a wide sweeping arc at the bottom of the slope, ultimately heading back upslope, forming a corral-like structure. The major fence generally runs in an east/west direction across the plateau, and wooden pieces of the fence are scattered in a near continuous trail of overlapping tree boles that often attain a height of 0.30-0.60 metres (Figure C. 6).

In conjunction with the major fence, two minor fences have been constructed on either side of the major fence. The two minor fences (minor north and minor south) are much shorter, and most of the wood in the minor fences is in direct contact with the ground, and they are not made up with a series of as many continuous individual logs as those found in the major fence (Figure 3. 2).

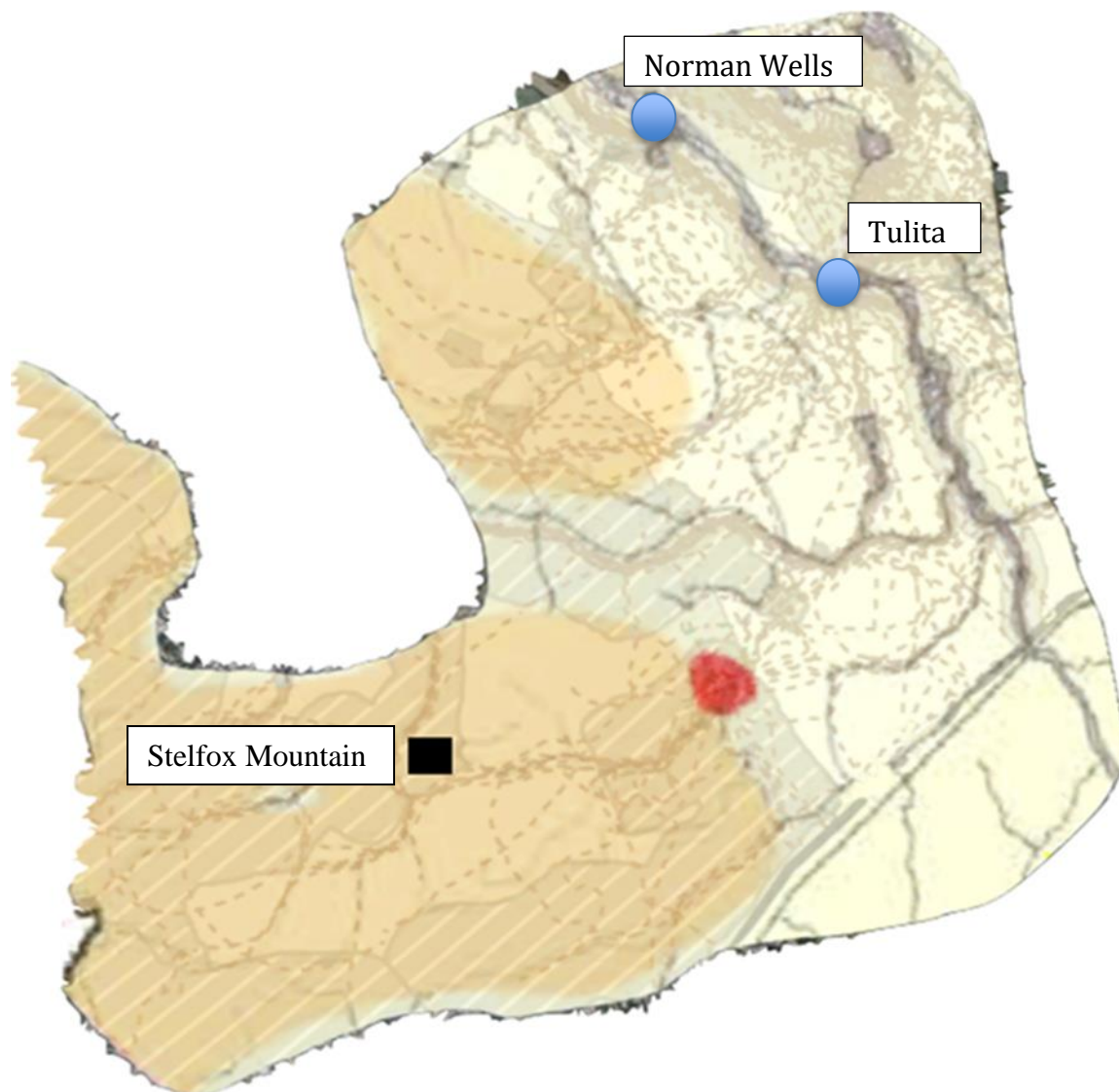


Figure 3. 1 - Sahtu traditional trails denoted by broken lines (Sahtu Land Use Planning Board 2010. Map 5). Redstone Herd range in orange, Drum Lake calving ground in red (Wilson and Haas 2012. Fig. 4), Stelfox Mountain study area in black.



Figure 3. 2 - Lightly constructed portion of the minor-north fence.

3.4 Methods

3.4.1 Dendrochronology

Standard dendrochronological methods were employed to determine the general pattern of growth, shared by living trees near the archaeological site. The pattern, a result of the differential deposition of annual growth rings, became the mechanism through which the archaeological features were dated, and past use of the site was evaluated. Dendroarchaeological data were obtained from Beckhusen 2019 (see Chapter 2).

The dendroarchaeological project placed 81 individual fence boles in time and space from all three fence lines (Chapter 2). Spatial data for the archaeological cross-sections were plotted using ArcMap™ 10.5. Applying a GIS to manage the data allowed for different visual configurations to be explored. The locations and end-dates of specific archaeological wood could be compared against others, or against their immediate physical environment, thanks to the attribute based filtering options available within the program.

3.4.2 Remote Sensing

A DJI Phantom 4 UAV was flown over the site and surrounding area to obtain data using a high resolution camera capturing the visible red-green-blue (RGB) spectrum, and a Parrot Sequoia™ sensor to obtain multispectral green, red, red-edge, and near infrared (NIR) wavelengths. The UAV was flown 60 m above the fixed ground control point (GCP), with paths plotted to follow transects that would capture images with 80% front-lap and 60% side-lap in both the RGB and NIR spectrums (Figure 3. 3). The overlapping still images were differentially corrected to ± 2 cm.

3.4.2.1 Image Preparation

The images were combined to construct both a 3D model of the site, and a high resolution (± 2 cm (2.72 cm/pixel)) orthomosaic using Pix4D. The orthomosaic files were added to ArcMap as layers allowing for traits of the site to be evaluated and incorporated into the dendroarchaeological data layers.

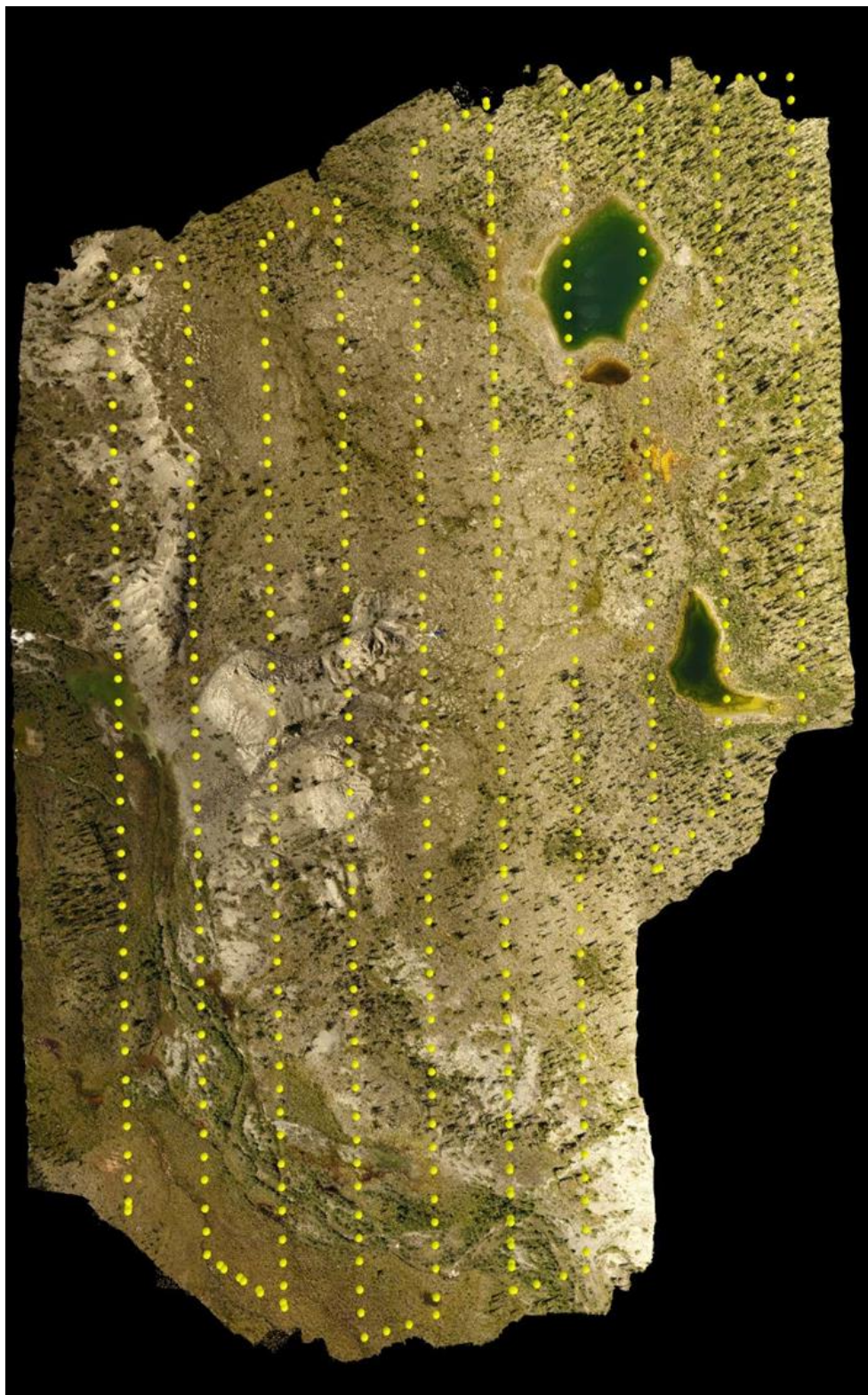


Figure 3. 3 - UAV flight path and image capture locations over the entire study area, including the plateau and the adjoining embankment.

3.4.2.2 Analysis

Remote sensing data was used to determine relationships between multiple datasets, topography, NIR reflectance, and the physical extent of the fence systems. Vegetation indices are sensitive to soil conditions impacted by variables such as soil compaction, or differential water availability through time.

It was postulated that the areas of the site that witnessed high densities of caribou or other animal traffic (e.g. kill zones) would exhibit traits associated with increased soil compaction relative to low activity areas. Vegetation is susceptible to local soil conditions, such as compaction, which may indicate activity areas. Vegetation indices and NIR visualization were used to attempt to identify possible areas of compaction that could then be spatially related to the fences.

Calculated index values indicate the differential health of plants or grasses within the area surveyed by the UAV. The NDVI is an indicator of overall plant health, and GNDVI is more sensitive to the chlorophyll content of the plant community. Both may aid in determining where plant health has been directly affected, such as by soil compaction. Similarly, NIR reflectance can indicate soil properties that may not be observable using the vegetation indexes. Both ArcMap and Pix4D were also used to generate and display these results.

3.5 Results

3.5.1 Dendroarchaeological Results

End-dates were determined for eighty-one pieces of archaeological wood. The years spanned from 1314 – 1876 C.E., with 69 cross-sections falling into one of two date clusters (Chapter 2, Figure 2. 6). The clusters, indicate two main periods of use, with the second (1584-1746 C.E.) being the longest, and representing the highest number of end-dates at 54. The archaeological end-dates have been divided into six groups, and further into 25 sub-groups (Table 3. 1). Based on the sub-groupings, use during the 1584-1746 period appears to have been episodic, with up to an estimated 14 use periods.

A substantial difference in the end-dates of the archaeological wood of the corral feature, and those of the three fences on the plateau exists (Table 3. 2). It seems probable that the corral was added after the fences were originally built, to better utilize a changing landscape.

	SUB	CODE	LYOG		SUB	CODE	LYOG		SUB	CODE	LYOG		SUB	CODE	LYOG
1420	1	16LD020	1314	1750*	9	16LD064	1584	1750*	16	16LD069	1665	1800	23	16LD048	1771
		16LD055	1379			16LD028	1588			17KD010	1667		24	17KD006	1793
		16LD004	1385			16LD043	1591			17KD002	1675		17KD005	1797	
1500*	2	16LD045	1421		10	16LD057	1596		17	16LD007	1678	1880	25	16LD010	1843
	3	16LD011	1426			16LD018	1597			16LD001	1681			16LD059	1876
		16LD052	1429			16LD054	1597			17KD001	1684	16LD005	9999		
		16LD013	1433			16LD003	1598			17KD009	1686	NA	NA	16LD024	9999
		16LD060	1437		11	16LD062	1610			16LD030	1687	16LD051	9999		
	16LD012	1438	12			16LD070	1617			16LD036	1687				
	4	16LD021			1445	16LD058	1619			17KD014	1688				
		16LD041			1447	17KD007	1623			18	17KD011				1698
	5	16LD037	1457		13	16LD027	1630		16LD053		1699				
		16LD019	1460			17KD013	1632		16LD065		1703				
		16LD025	1460			16LD056	1634		17KD008		1703				
		16LD049	1461			16LD040	1637		16LD015	1707					
	16LD050	1463	16LD034			1640	19		17KD003	1713					
	6	16LD016	1477			16LD068			1640	16LD042	1715				
		16LD044	1479			17KD004	1640		20	16LD017	1721				
	7	16LD047	1519			16LD029	1642			16LD026	1723				
		16LD002	1520			16LD061	1642			16LD035	1723				
	1580	8	16LD032			1556	16LD063			1642	16LD033				1724
16LD023			1561		14	16LD006	1646		21	16LD022	1732				
			16LD038			1647	16LD039			1732					
			16LD008			1649	22		16LD031	1739					
			16LD046			1651			16LD067	1741					
			16LD009			1657			17KD012	1742					
			15		16LD066	1660	16LD014		1746						

Table 3. 1 - End dates, sorted into groups representing a shared period of time. The groups have been further divided into sub-groups of finer temporal resolution. The main groups are denoted by the calendar in which they fall under, their code identifying when and from where they were taken, and their respective end-dates denoted as LYOG. End-date groups falling into one of the two identified date clusters are denoted with an asterisk (*).

MAJOR				NORTH				SOUTH				CORRAL			
45 End Dates	FYOG	END DATE	YEARS	12 End Dates	FYOG	END DATE	YEARS	10 End Dates	FYOG	END DATE	YEARS	14 End Dates	FYOG	END DATE	YEARS
25	1133	1460	327	1	1490	1681	191	14	1623	1746	123	1	1470	1684	214
26	1489	1723	234	2	1366	1520	154	15	1488	1707	219	2	1587	1675	88
30	1496	1687	191	3	1103	1598	495	16	1046	1477	431	3	1572	1713	141
32	1172	1556	384	4	1113	1385	272	18	1373	1597	224	5	1642	1797	155
33	1487	1724	237	6	1448	1646	198	19	1251	1460	209	6	1686	1793	107
35	1609	1723	114	8	1523	1649	126	20	972	1314	342	7	1350	1623	273
37	1217	1457	240	10	1762	1843	81	22	1652	1732	80	8	1533	1703	170
40	1257	1637	380	11	1232	1426	194	23	1400	1561	161	9	1458	1686	228
41	1137	1447	310	12	1089	1438	349	17	1489	1721	232	10	1503	1667	164
42	1544	1715	171	13	1220	1433	213	21	1149	1445	296	11	1494	1698	204
45	1171	1421	250	7	1509	1678	169	AVERAGE	1344	1576	232	12	1518	1742	224
47	1268	1519	251	9	1297	1657	360	MEDIAN	1387	1579	222	13	1524	1632	108
48	1349	1771	422	AVERAGE	1346	1580	234	MAXIMUM	1652	1746	431	14	1525	1688	163
49	1142	1461	319	MEDIAN	1332	1622	196	MINIMUM	972	1314	80	4	1549	1640	91
52	1185	1429	244	MAXIMUM	1762	1843	495	ADJ. AVG.*	1352	1588	226	AVERAGE	1529	1696	166
70	1515	1617	102	MINIMUM	1089	1385	81					MEDIAN	1525	1687	164
53	1475	1699	224	ADJ. AVG.*	1330	1573	223					MAXIMUM	1686	1797	273
54	1387	1597	210									MINIMUM	1350	1623	88
56	1439	1634	195									ADJ. AVG.*	1531	1693	164
57	1472	1596	124												
58	1454	1619	165	19th Century End Dates											
59	1623	1876	253												
60	1209	1437	228												
61	1438	1642	204									ALL FENCE - 81 End Dates			
62	1502	1610	108										FYOG	END DATE	YEARS
63	1440	1642	202									AVERAGE	1403	1617	215
65	1470	1703	233									MEDIAN	1448	1642	209
66	1487	1660	173									MAXIMUM	1762	1876	495
67	1620	1741	121									MINIMUM	972	1314	80
68	1409	1640	231									ADJ. AVG.*	1404	1618	213
69	1545	1665	120												
27	1395	1630	235												
28	1465	1588	123												
29	1558	1642	84												
31	1549	1739	190									MAJOR, NORTH, SOUTH - 67 End Dates			
34	1336	1640	304										FYOG	END DATE	YEARS
36	1337	1687	350									AVERAGE	1376	1601	225
38	1358	1647	289									MEDIAN	1409	1634	219
39	1437	1732	295									MAXIMUM	1762	1876	495
43	1403	1591	188									MINIMUM	972	1314	80
44	1379	1479	100									ADJ. AVG.*	1376	1601	223
46	1420	1651	231												
50	1290	1463	173												
55	1067	1379	312												
64	1474	1584	110												
AVERAGE	1391	1612	221												
MEDIAN	1437	1637	228												
MAXIMUM	1623	1876	422												
MINIMUM	1067	1379	84												
ADJ. AVG.*	1393	1612	220												

*Adjusted Average (ADJ. AVG.) excludes maximum and minimum values from calculations.

Table 3. 2 - Summation of all archaeological end dates.

The corrected average (Appendix B) end-dates for the north, south, and major fences (exclusive of corral wood) are 1573, 1588, and 1612 C.E. respectively, while the corrected average of the corral cross-sections is 1693. Isolating the corral feature indicates that it was not part of the original complex, but had been added at some point more recently (Figure 3. 4).

3.5.2 Remote Sensing Results

UAV obtained data provided several insights into the changing physical environment of the site, and the physical characteristics of the fence complex and surrounding area. The environment and its relationship to the fences is indicated through the vegetation indices (Figure C. 7Figure C. 8Figure C. 9) and site topography as observed using digital terrain modeling (Figure 3. 5). Inferences were made regarding activity areas, those with relatively higher levels of potential soil compaction that influenced local vegetation, and a changing physical environment that directly impacted fence design and use.

Remote sensing also allowed for site observations of things not visible from the ground. Physical characteristics of the fence complex, as well as those of the surrounding landscape, such as diachronic variations in valley and plateau water levels, differential soil character characteristics (discussed below) were noted during data analysis, and incorporated into the use history of the project. Further, a previously unobserved portion of the north fence, at its western edge, was identified.

Kill sites of this nature are often associated with processing, cache, and camp sites, areas with archaeological potential surrounding the complex, that may reflect those activity areas, have also been identified. Locating potential areas for their existence via the manipulation of the remote sensing data (Figure C. 10) will save time for survey crews and tell the Caribou Fences' story in a much more holistic way.

3.6 Discussion

Combining the two datasets provided the mechanism through which the site's use history could be evaluated and conclusions made in a way not possible using only one approach. Undoubtedly there had been many uses of the fence complex over the years. Two of them, representing the earliest and most recent, are outlined using available data.

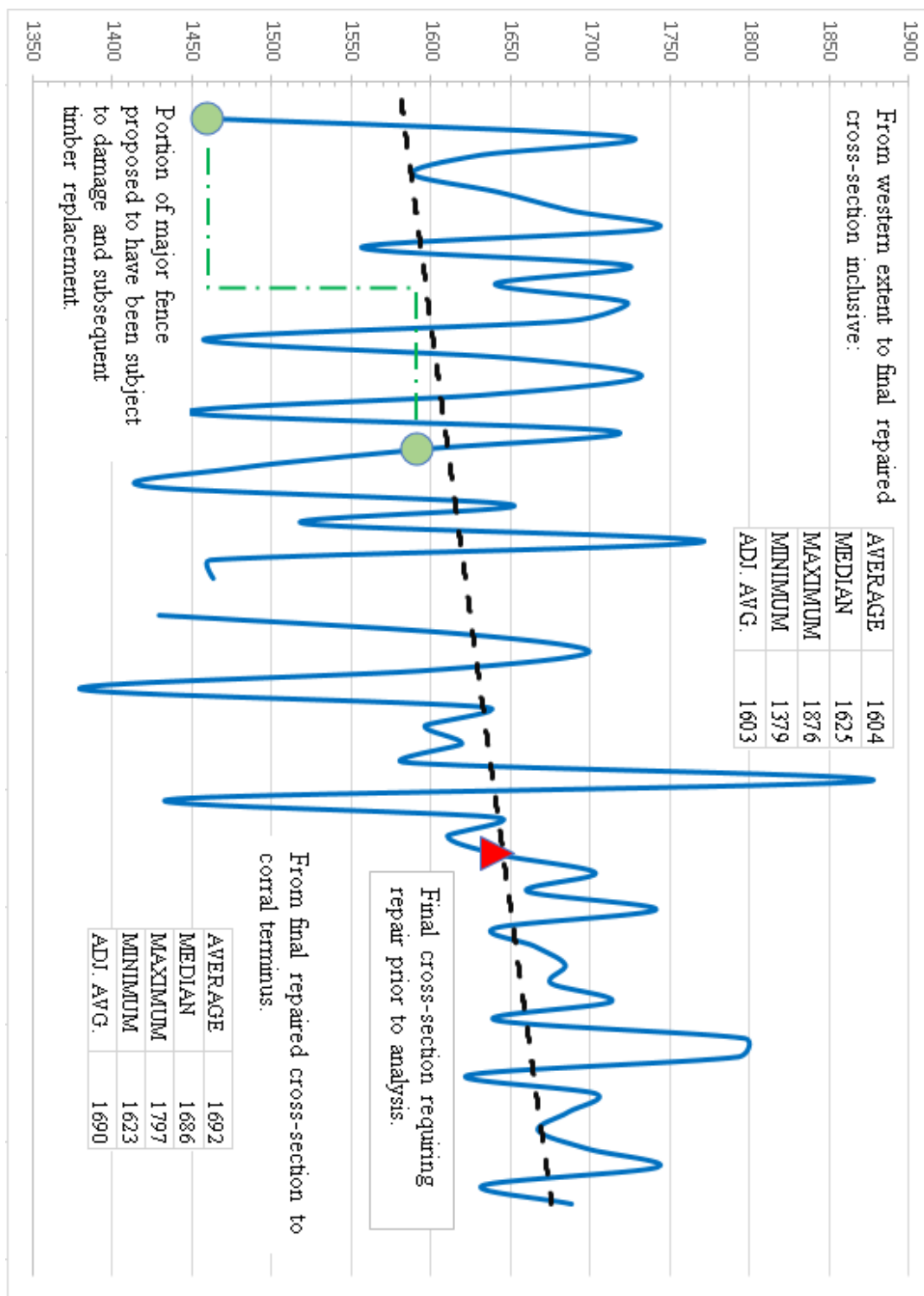


Figure 3. 4 - Major fence end-dates from western extent of major fence to corral terminus (blue line). The red triangle indicates the final cross-section requiring repair within the major fence. The green circles indicate the portion of major fence proposed to have been subject to damage and subsequent timber replacement. The black trendline demonstrates the appearance of more recent end-dates moving east from the western edge of the major fence, to the corral terminus.

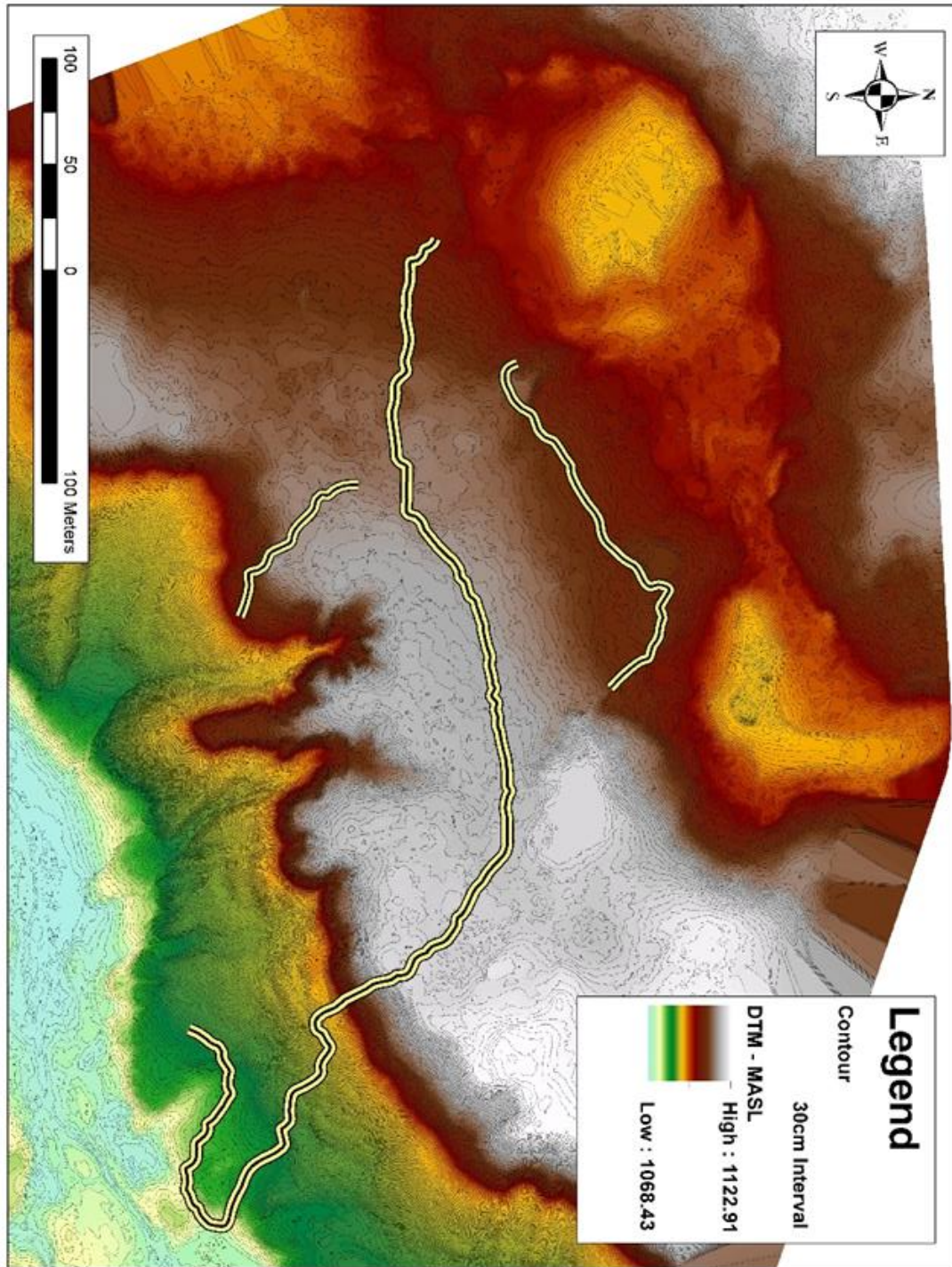


Figure 3. 5 - MASL and DTM map with contours at 30cm intervals.

3.6.1 Early Use - When and How

NIR data indicates discrete vegetation changes in the visible and multi-spectral spectrums between the plateau, and those of the valley (Figure 3. 6). The differences are possibly due to the long-term presence of ice or water, standing or otherwise, at or near where the changes occur, but would require further investigation to determine causal factors.

The NIR indices demonstrate a noticeable difference in reflectivity at ~1109 metres above sea-level (MASL). Interestingly, no observable portion of the fences, excepting the corral, falls below the 1109 MASL mark. Further, both the western terminus of the major fence as well as that of the southern fence occurs at 1109 MASL, despite the ~200m linear distance between the two points. While possibly coincidental, this seems unlikely; the logical conclusion being that a natural endpoint to fence construction existed. Thus, it would seem that some physical phenomenon occurred at 1109 MASL, and that this phenomenon was of a type to affect hunting practices, and be reflected in the NIR data. While the data do not indicate the nature of this phenomenon, one possibility that would have clearly affected hunting practices was if the area once held a (perched) lake; the two ponds that are currently in the area would be the remnants of such a lake. Another possibility, given that much of the use-history of the fence falls within the Little Ice Age, is that this valley held ice, or permanent snow for most of the year. Regardless, it would seem that at this early stage of use, the fence extension ending with the corral was unnecessary.

Applying NIR and dendroarchaeological data, an “original” extent of the major fence can be proposed. NIR data indicates possible soil compaction to be relatively high at the fences’ eastern edge, more so than that of the surrounding area. Close inspection of the multi-spectral imagery indicates that there may be past game trails passing the fence at that location; this would require ground truthing to confirm. Dendroarchaeologically, no dates from sub-groups one through eleven (1314-1610 C.E.) inclusive, are found between the proposed eastern terminus and the corral’s end (Figure 3. 7). Of note is that the missed section of the north fence that was not identified in the field, does not fall below 1109 MASL, and its edge sits ~6 metres from that elevation. Sub-groups one through eleven (inclusive), are exclusively found in the north, south, and early major fence, as are all archaeological cross-sections that had required extensive repair in the laboratory prior to analysis.

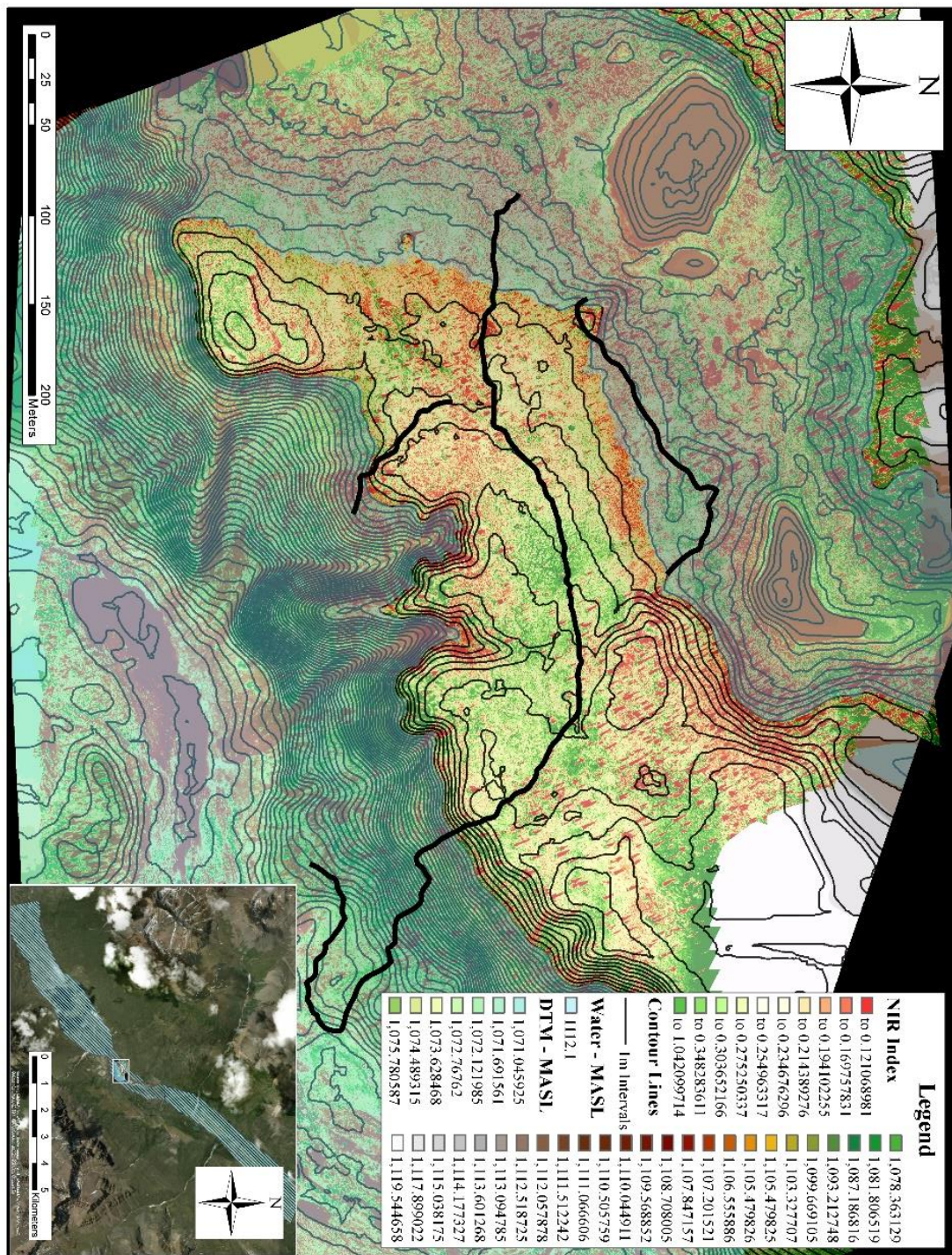


Figure 3. 6 - DTM modelling water level shaded at 1112.1 MASL, with NIR index, 1m contours, and inset map depicting hypothesized past water flow over plateau.

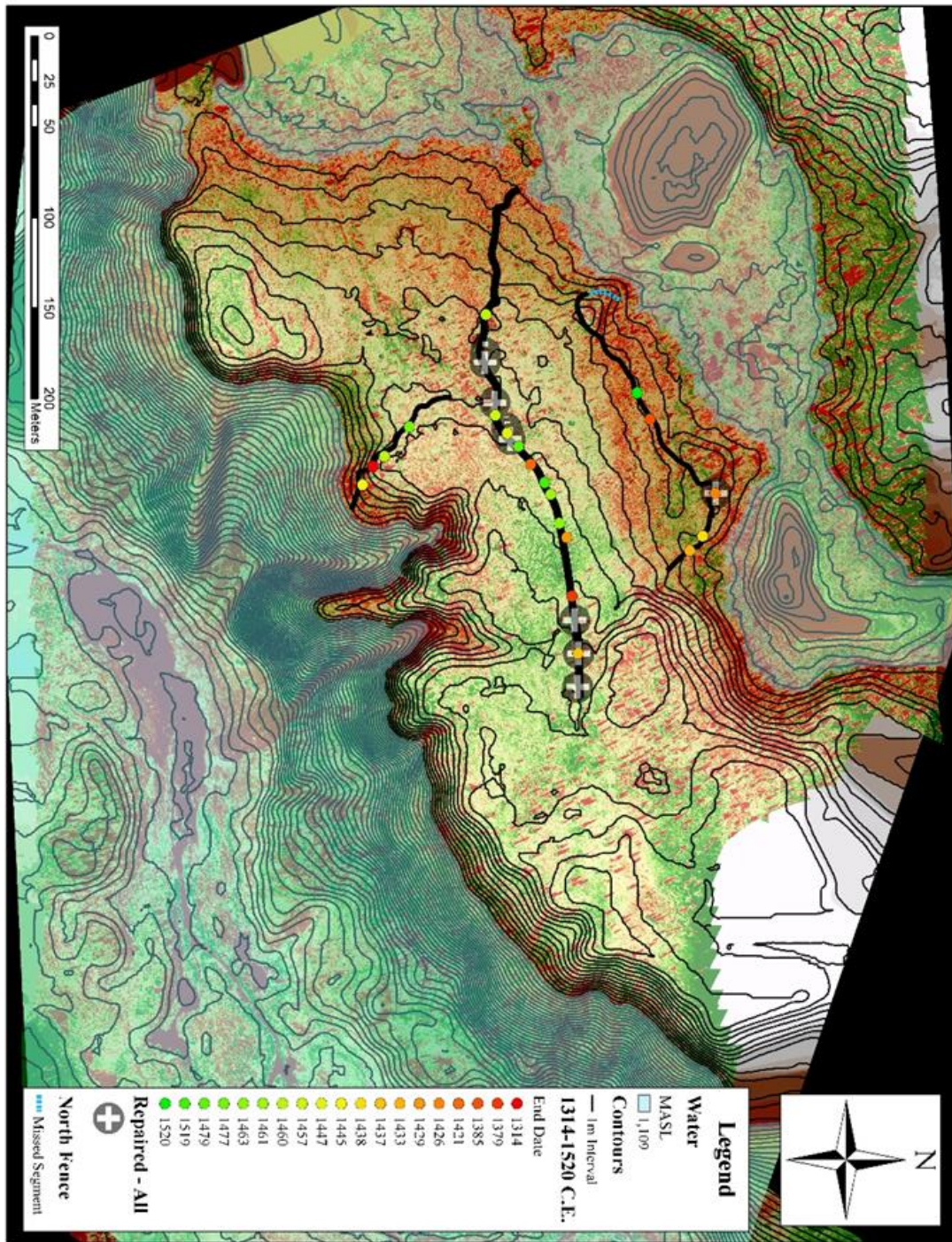


Figure 3. 7 - "Early use" DTM modelling water level at 1109 MASL, NIR index, and 1m contours. Includes unobserved western extent of the minor-north fence (blue dots), archaeological end-dates to 1520, and locations of cross-sections that required extensive repairs in the laboratory prior to analysis.

It is likely that, if they existed, elevated water levels factored into the hunting strategy as this is an oft employed method (Benson 2011; Gillespie 1976; Gordon 2003; Kendrick 2000; Speth 2013), either by hunters awaiting at the predicted location of the animal's migratory crossing (Bathurst Caribou Range Plan 2018), or by directing them towards a crossing. The crossing impedes movement, making the harvest of otherwise quick moving animals, an easier task. One such possible crossing would have been approximately 40 m across with a depth of no more than 2 m. Near that location, there is possible gap in the north fence, of ~15 m, associated with an increased NDVI value. This may indicate soil compaction corresponding to increased activity levels consistent with what can be expected when funneling a large number of animals through a restricted opening (Figure 3. 8). The portion of the north fence that was not observed prior to the evaluation of the UAV footage curves to the northeast from the western edge of the fence. Adjacent to it is another instance of increased relative NDVI values that, again, may indicate another high-traffic kill-zone.

On the south side of the major fence, kills may have taken place by steering animals towards a “pinch” (Figure 3. 9) which would make their numbers more manageable as they passed through to meet awaiting hunters. Those not immediately harvested could be targeted near the shoreline as their movement became slowed. The pinch location is the area with the greatest damage and instances of repair within the major fence. Seven of the 11 cross-sections identified as requiring repairs are located within the area of the pinch. This indicates a high degree of activity and impact along that section. GNDVI values increase at that point as well, flaring from the pinch point before concentrating toward the water.

3.6.2 Recent Use – When and How

The second temporal use history appears to be a longer period, likely episodic, with fence sample end dates ranging from the late-16th to mid-18th centuries. It is during this temporal period that the corral structure was added to the major fence. The extension may have been made possible by a decrease in water level, or snow-pack along Stelfox Creek, or could simply reflect a change in the way the system was used. It seems likely that the two modern water bodies to the north of fences were one larger pond, allowing for the continued use of the funnel north of the major fence, which was maintained well into the 19th century. This permitted the use of multiple

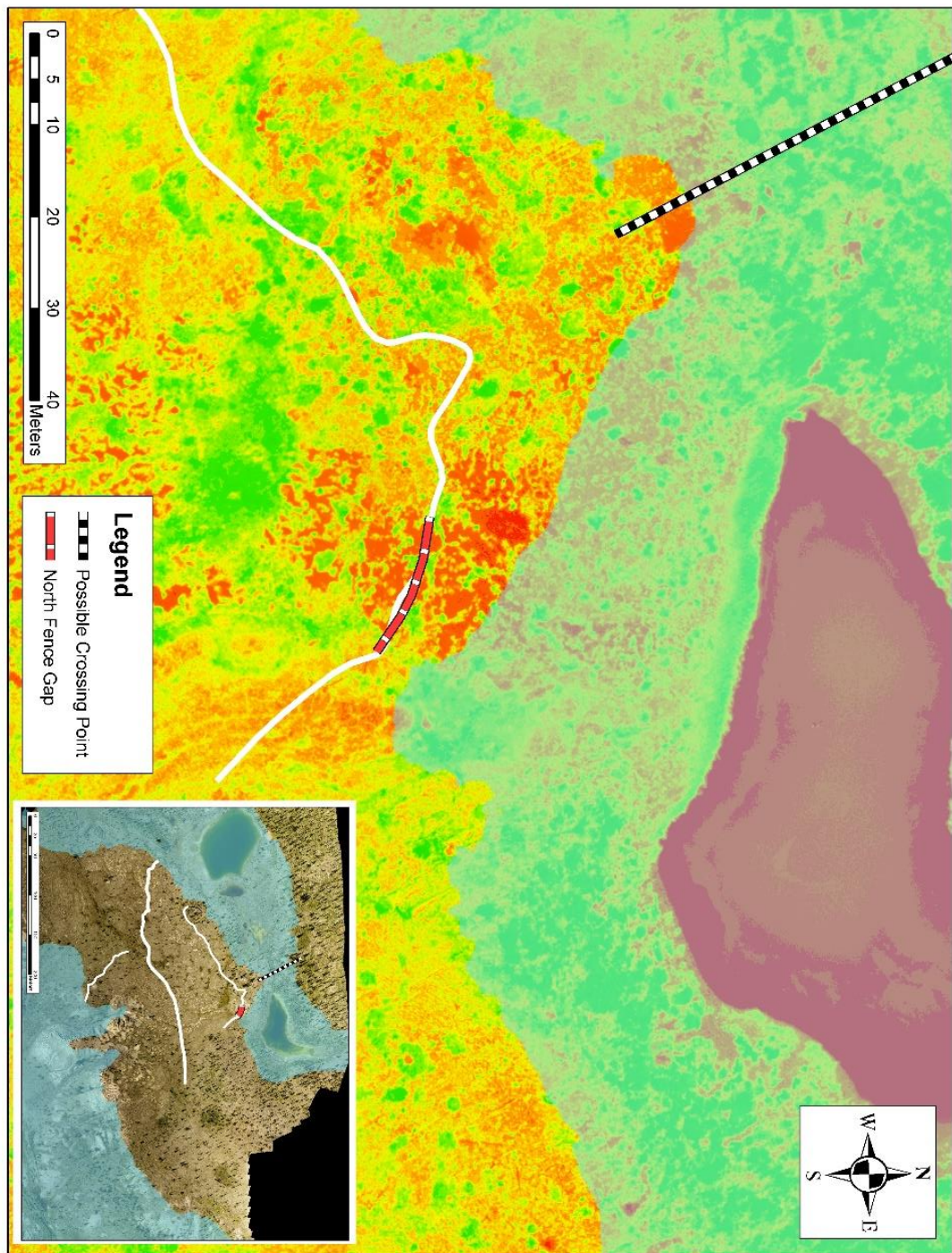


Figure 3. 8 - Close-up of the north-fence gap, relative to potential water crossing. Note the differential NDVI returns associated with the gap area.

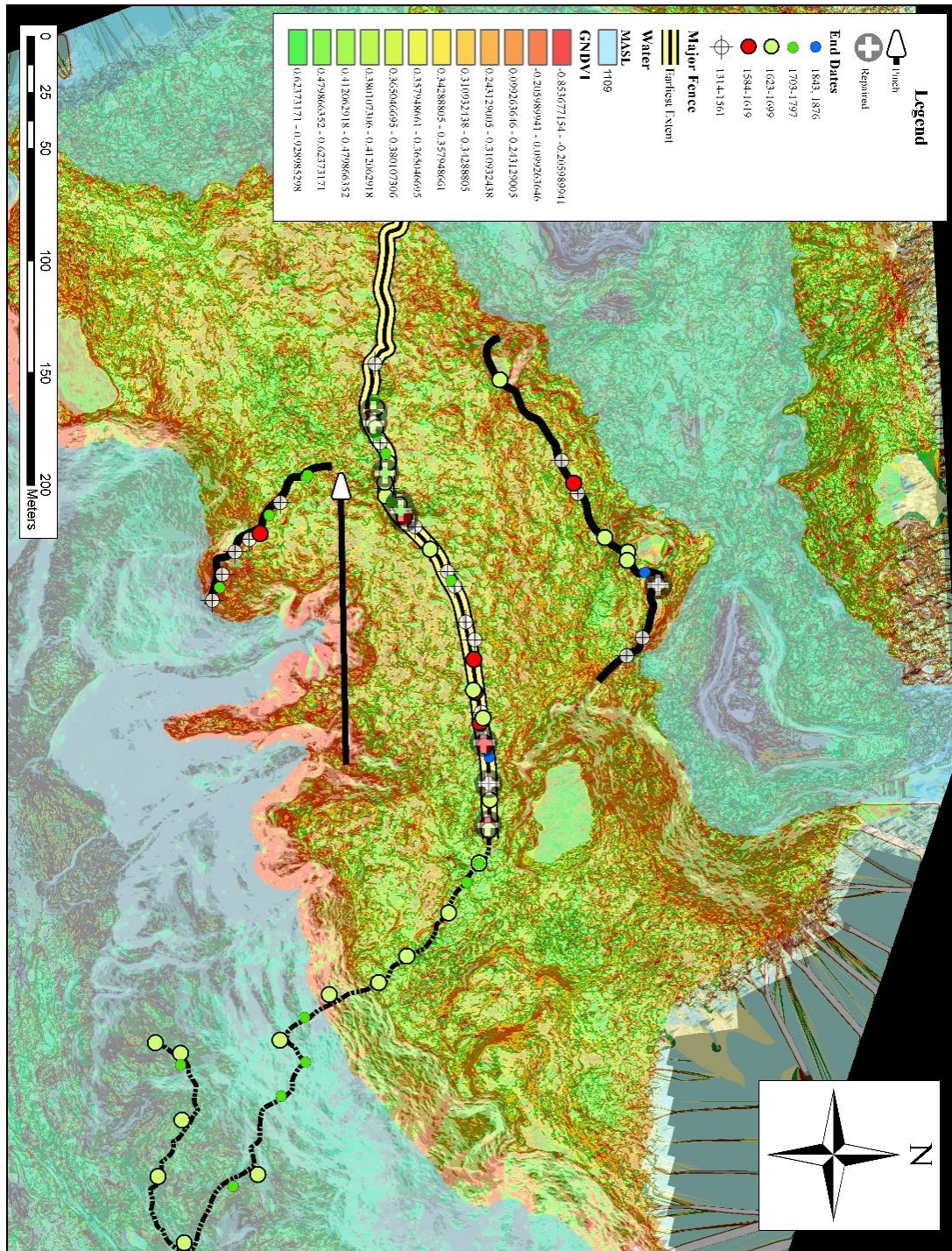


Figure 3. 9 - "Early use" with all end-dates plotted, the proposed earliest extent of the major fence, the "pinch point" indicated by the arrow, and locations of cross-sections requiring extensive repairs in the laboratory prior to analysis. GNDVI included, with areas below 1109 MASL shaded.

kill zones when combined with the corral at the lower elevation. No dates preceding 1623 C.E. are present among the cross-sections obtained from the proposed addition to the major fence, including the corral feature (Figure 3. 10).

Fences of this sort are designed on the premise that caribou tend to follow along obstructions rather than cross them (Benson 2011; Blazina-Joyce 1989; Brink 2013; O'Shea et al. 2014; Warbelow et al. 1975). That being the case, there is no obvious way available to steer them into the corral. Heading east along the plateau, they would have to be south of the major fence in order to not have to cross it. From that side, there is no easy way to intercept them. The more easterly margin of the south fence would impede movement, while moving them along the top would require them to be move through the pinch-point from the narrow side, which would require hunters to "thread the needle". If the herd is moving west, again there is no direct way to get them into the corral without having to cross the obstruction. The same is the case if they are coming from higher elevation

One method, which appears to work from either direction, as long as the movement is along the valley bottom, is to have hunters herd them upslope, west of the corral. Close inspection, using the NIR band, revealed features consistent with free standing snares (Figure 3. 11). These were observable in the corral, as well as a channel to the west. It is possible that hunters pushed the animals upslope, where movement would be restricted by local topography. As the herd climbed toward the plateau, some would become entangled in snares, and strangle as they struggled to free themselves and gravity pulled them back. This would be similar to the function of some kill sites further north (Blazina-Joyce 1989; Warbelow et al 1975). At those sites, corrals were used, but within tree lines, and upslope. Caribou were caught up, and would slide back downslope allowing easier kills. Aside from the snare structures, there are numerous scattered timbers that may very well have acted as an extension of the south fence that would keep the animals contained. Given their position, situated on a steep incline on what could have been an active drainage channel, the timbers could easily be the washed-out remnants of the south fence.

Those caribou that made it through the snares would continue their ascent until they arrived at the major fence. From there, the caribou would follow the fence line east until the descent towards the corral.

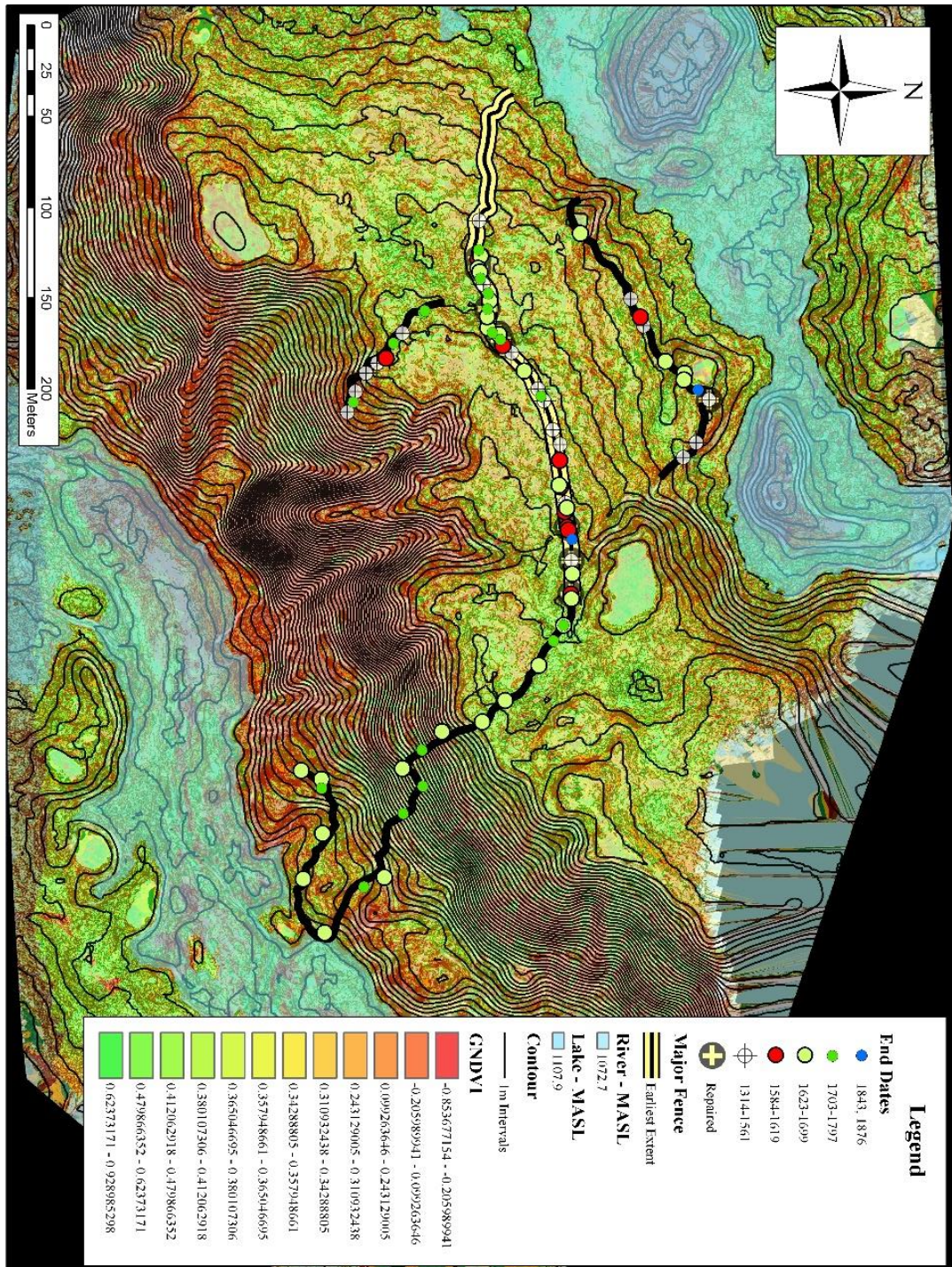


Figure 3. 10 - "Recent use" with all end-dates plotted, valley river at 1072.7 MASL, lake on plateau, and GNDVI. Locations of cross-sections requiring extensive repairs in the laboratory prior to analysis, the earliest extent of the major fence, and contours at 1m intervals.

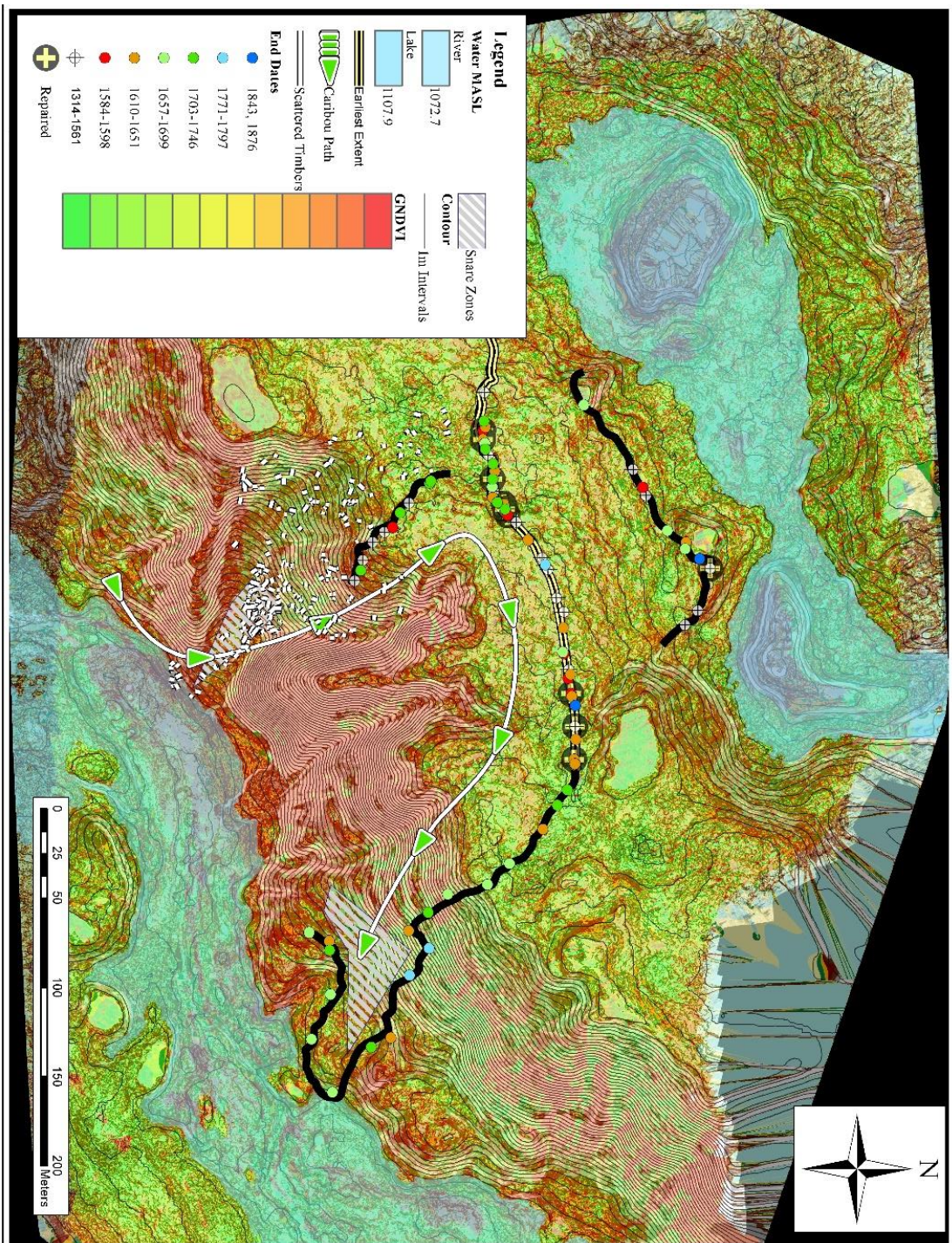


Figure 3. 11 - "Recent use" model with the additions of snare zones, scattered timbers, and potential caribou path.

This method would allow two potential kill sites, and work without forcing animals to cross the linear obstruction provided by the fence complex.

3.7 Conclusion

This research was designed to provide insights regarding past use of the Moose Horn Pass Caribou Fence complex: How old the fences are, and how were they employed by ancestral Shúhtagoíine. Applying empirical data to the evaluation of the network allowed both objectives to be met, and subjective statements to be made with confidence. Outcomes included the determination of end-dates ranging from 1314-1876 C.E. for 81 archaeological cross-sections. Those dates, most of which fall into two clusters pre-dating the 19th century, indicate site use far predating the historic meat trade. The two most recent end-dates (1843 and 1876), likely indicative of maintenance or repair, implies that the complex was still utilized near the time of the meat trade economy. The spatial distribution of those dates appears to be linked to changes in the landscape as indicated by the remote sensed multi-spectral imagery. Locations of obvious repair and maintenance to the fence have been identified, and subsequently explained as being related to locations of high activity, where impacts to the timbers during harvest caused observable damage.

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4.0 Conclusions

4.1 Major findings of Chapter 2

A 1044-year long chronology, developed by crossdating the growth patterns of living trees with those of archaeological wood, allowed end-dates to be determined for 81 cross-sections cut from the fence complex. The temporal distribution of those end-dates indicate episodic periods of use well predating those that would be expected had the complex been built, and used, in the late-19th century, as would be the case had it been used exclusively during the historic meat trade.

Research of the Moose Horn Pass Caribou Fence has provided significant data demonstrative of the conditions in which ancestral Shúhtagot'ine constructed, and used the fence complex. Marker years (Table D. 3), used to crossdate the living, snag, and archaeological ring patterns provided an effective tool for visual crossdating. A product of generally poor growing conditions, they were observed in trees with minimal, or completely absent ring deposition in a given year. Discrete events within a growing season might also serve as a marker, one that did not require growth indices to be shared between individual series. Unseasonal frost events, causing damage to the cellular structure of rings, allowed crossdating samples that displayed varied ring widths in the affected year. The years 1877, 1850, and 1783 were markers of overall poor conditions, 1899 and 1799 both experienced damaging frost. The tree rings recorded the conditions of specific years, the same conditions experienced by the Mountain People.

4.2 Major findings of Chapter 3

Eighty-one archaeological cross-sections were dated. Their end-dates, ranging from 1314-1876 C.E. indicate that its use was not recent, and short lived, but rather was episodic over a period lasting, potentially, 350 - 450 years. The two most recent end-dates (1843 and 1876), likely indicative of maintenance or repair, implies that the complex had been utilized near the time of the meat trade economy, but that is not the only period of use represented by the dates. Locations of obvious repair and maintenance to the fence were identified, and inferred as being

related to high activity areas affected by damage caused by impacts to the timbers occurring during animal harvesting.

The data obtained via remote sensing, augmented by the spatial and temporal distribution of the end-dates, suggest that the fence system was not static in its deployment, but was redesigned over time to potentially best exploit a changing landscape.

4.3 Overall Thesis

The empirical data gathered during the course of this research are instrumental in exploring the social implications of the site and its archaeological record.

By applying remote sensing to the dendrochronological data, the spatial and temporal aspects combine to expose patterns in fence construction and maintenance that would not be otherwise apparent. Mapping the end-dates and locations of damaged cross-sections provides opportunities to interpret results beyond simply dating the fence complex. It is only in this way that it could be proposed that site use was diachronic. A causal relationship existed between the two. One which did not hinder the use of the fence complex, but led to adjustments in its physical design, and how it functioned in concert with the landscape.

4.3.1 Thesis Conclusions

End dates were established for all but three of the 84 archaeological samples. Those dates illustrate two significant periods of use, with the most recent covering an extended number of years relative to its counterpart, and likely representing several concentrated use periods during its span. Two of the 84 cross-sections represent years in the 19th century. These two, appearing well after those preceding them, indicate the use of the site during the time of the meat trade with European settlers, which coincides with Shúhtagot'ine oral history.

Certain complications are inherent to this research. It must be acknowledged that old-wood may have been used in construction, and that any end-dates may not reflect whether a particular timber represented the harvest of a living, or dead tree. By extension, if old-wood is present in initial construction, it cannot be definitively stated to what extent it is present, or to what time period it belonged. This may mean that the fence was built, and used entirely during the historic meat-trade, rather than episodically for centuries as the dates themselves would indicate. It is also the case that old-wood may have been used in the repair and maintenance of

the fences. Living trees harvested for this purpose might be observed as outliers to the end-dates of surrounding timbers, but old-wood might not be recognizable in such a context. It must therefore be considered that old-wood may have been a principle component of construction, at any point during the site's centuries of use.

Nash (2000) wrote, "...all that noncutting dates can provide is a terminus post quern, a date after which a given event must have occurred". It is with this in mind that the interpretation of the archaeological end-dates was undertaken, by focusing on whether spatial and/or temporal patterns could be observed. A shared cluster of end-dates and an observable pattern to their distribution among the features, would indicate there being periods of use over time, rather than a single, or short-term use. Although this leaves the research outcomes lacking in the determination of actual calendar years, it does provide a mechanism through which the site's use-history can be examined.

It is likely that the corral feature, and a portion of the major fence, were not constructed at the same time as the rest of the complex, but were added later to suit the changed physical environment or manner in which the fence system was being used. The implication being that the complex was not originally intended to steer animals to a corral, but was designed to harvest animals at locations along the plateau. The portion of the major fence with evidence of relatively high incidents of damage and repair is indicative of impact and other activity consistent with being either a kill-zone, or an area of concentrating the animals prior to the kill. In either case, a corral feature was not a necessary component of fence use.

Periods of differential environmental conditions may prove helpful in developing models of past human land-use. The extended chronology produced from the Stelfox Mountain trees permits comparisons with other chronologies in, or near, the Mackenzie Mountains, that may indicate differences between alpine and peripheral growing conditions in a given year. An example is the comparison of Stelfox chronology to those from the north and south of the site. The three are very similar, excepting for a period between the middle and late-19th century. In addition to short-term events, long-term changes relevant to human land use might also be looked at by comparing chronologies. The white spruce trees proximal to the fence complex demonstrate a high degree of resilience to the growth limiting factors of the environment. Young trees (<50 years) are the exception, not the rule. Most trees have survived well over a century, with some

being over three centuries old. One implication of this is possibly that the conifers are not reproducing as they once did. That, in conjunction with what appears to be a fairly recent establishment of deciduous trees, possibly willow (*Salix* sp.) at lower elevations (Figure C. 11), may be indicative of the early stages of a change in forest type, one less favourable to coniferous trees and better suited to those preferring a warmer environment.

Across sample types, there is an observable decrease in individual tree age, the number of growth rings present, indicated by LYOG rings through time to the current population (Figure C. 12). This may mean that spruce trees are repopulating the area, and are therefore younger overall. Alternatively, it may mean that they simply are not as long lived as they once were; further study is required. Steve Mamet of the University of Saskatchewan conducted dendrochronological research at sites approximately 85 km west of Stelfox Mountain (Mamet and Kershaw 2012) and found that numbers of individual trees growing at a specific moment in time increased over time. The FYOG of the oldest tree from the Mamet and Kershaw (2012) study, 1707 C.E., lacks the temporal depth necessary to corroborate or refute the findings revealed here. The selective sampling of this project was not designed to address such questions, but can still serve to direct future research designs, which will require sufficient temporal depth to observe patterns, as demonstrated by the previous comparison.

Currently there is a concern regarding the preservation of the site as it is subject to the threat of destructive events like forest fire, and ground movement. This study helps preserve the archaeological resource through producing a chronology and use history of the fence.

4.4 Implications

Much of what has been argued within these pages cannot be taken as “fact”, but as potential explanations of the data presented. As is always the case, further study is required to expand upon the knowledge gained. Specific suggestions regarding how research may be advanced and the interpretations presented here-in tested includes:

- 1) Archaeological investigations targeting, through pedestrian survey and subsurface testing, those areas proposed to have hosted significant past hunting activity.

Camp and processing sites tend to be located fairly close to kill sites of this nature, but neither has been found yet. Identifying their locations would further explain the regional

organization and use of the area. Spatially, it would not be desirable to process within the kill zone, or too far away, nor would a camp be too close (or too far) from the kill and processing sites. Once they are discovered, a more holistic picture can be presented, and diagnostic artifacts and chronological investigations could be related to the dendrochronology to evaluate the temporal patterns to use-history suggested here. Examination of remote sensing data suggests some areas that may prove fruitful in this regard (see Figure C. 13).

- 2) Anthropological research, including interviewing elders, to document any accounts of the Moose Horn Pass Caribou Fence site in particular, if possible, and subsistence caribou hunting in general are recommended. This approach, although well outside of the scope of this project, would certainly be beneficial to the overall interpretation of the site.
- 3) Dendrochronological study incorporating a more complete sampling strategy than required for this project might provide a more complete understanding of past environmental conditions, and subsequent land-use strategies. Under this project's design sampling was performed to provide sufficient samples to allow crossdating of the archaeological wood. Future research, with a different sampling strategy, may provide a more accurate reflection of stand age and a more detailed statement of stand dynamics over time. This has the potential to yield important data regarding the local environment. The research has also led to discussions of future projects beyond the archaeology of the Moose Horn Pass Caribou Fence. Current possibilities include what may be dendroclimatic reconstruction extending further back in time than had previously been possible within the central Mackenzie Mountains. I am not aware of any dendrochronological site, near to Stelfox Mountain, that has yielded a chronology extending as far back in time. The Stelfox chronology has implications for and contributions to make to a variety of different research areas.

Perhaps more importantly is the opportunity presented during the course of a casual conversation with a Shúhtagot'ine Elder. It was then that two observations were made by the Elder, and shared with the writer:

- 1) Concern that younger generations are becoming less likely to accept the validity of traditional teachings.

- 2) Several instances of extremely poor weather conditions indicated during the more recent chronology, were recalled first-hand. Poor growth among the Stelfox trees in 1973 is an example of a key marker year in the chronology. With there being no instrument-recorded conditions from Stelfox Mountain for the year in question, there was no method available to determine the conditions affecting tree growth during that year. The Elder recalled 1973, and was able to fill in the knowledge gaps that would not otherwise have been possible. This information, provided by those that know the region best, could prove an invaluable resource in addressing the absence of instrument-recorded data from remote locations, such as Stelfox Mountain. There was even an indication that oral history accounts for other periods of environmental stress extending back into the 19th century.

Thus, it became apparent that a research partnership, combining TK with the science of dendrochronology, would be a worthwhile endeavor, providing value to all stakeholders, and serve to reaffirm the importance of TK to the generations to come.

From the “academic” side, such collaborative research will infuse the raw numbers with meaning. Where thousands of numbers are analyzed during the course of a project, it is easy to forget that they are all representative of a story. A period in which conditions were extremely poor would be seen and processed as ring-width measurements small in comparison to their neighbours. From the perspective of people living in the area, however, that period of time would likely have been highly significant, perhaps recorded and passed on through oral history. The whole story is that those years would have impacted those that lived them, and in a very real way may have had repercussions on present day culture. That is an important relationship, especially when working in the North, when it has sometimes been felt that southern scientists come, take what they need, and leave. They then use the acquired knowledge to generate research, which provides value to themselves, but not to the people whose home they had visited. When research takes place in the North, it is important to understand that it is not taking place in an external, detached way. But that the visitor is now a part of the relationship in which knowledge is created and shared. Even when all of the data are obtained from the land, it is the land that shares it.

4.5 Final Thoughts

Living within an ever-changing environment requires a deep understanding of the land and the relationships contained therein. The places, and the names that identify them, are vital to

the traditional Shúhtagot'ine way of life. They represent a portion of the TK passed from generation to generation. Places have been visited time and again for generations, but the activities taking place have changed as the people adapted. The site of the Moose Horn Pass Caribou Fence illustrates that the relationship with the land is maintained, even as environmental changes of various magnitudes occur. Even as use of the fence system required modifications between use-episodes, which may have been a year or a generation prior, the fences demonstrate that TK endures. Traditional ways are vital, as is the ability to change, adapt, and to modify and deploy technology in the most efficient ways possible. This is demonstrated in the design of the fence complex, the calendar years represented, and the environmental conditions present throughout its lifetime.

The area has a long history of human occupation, with hunting activity at Stelfox Mountain having been confirmed by GNWT archaeologists to have taken place thousands of years ago (Tom Andrews, personal communication 2016). The use of caribou fences, and other similar structures, are known to have occurred throughout subarctic zones all over the world, and even to more southerly locales like the Northern Plains. Corral structures, whether constructed *in toto* or incorporating pre-existing topographic features, have been employed throughout North America in the harvest of a multitude of ungulates. It is completely reasonable to expect that Moose Horn Pass has long been a site visited by mountain people, and that the knowledge of its use and means of construction passed from one generation to the next.

“...the Central Mackenzie Mountain Dene (Shúhtagot’ine) pasts and present ways of Life Language and Culture. The Caribou Fence represents our (Shúhtagot’ine) ancestors how they used to live and survive simply by using the fence method to capture different games big and small. Moose Pass Fence area and Bagaadeh (Keele River) below Natla and Bagaadeh river junction area (known to many as caribou flat), Shezal Canyon area are places where (Shúhtagot’ine) harvest games, very important area for the (Shúhtagot’ine).”

- Elder Leon Andrew (2018)

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Appendix A: Repair

Archaeological wood collected from the fence system often displayed some degree of rot that would prevent the cross-section from holding up to the preparation processes required prior to measurement. In most cases the structural integrity of the wood could be maintained by applying standard wood glue to the sample prior to trimming and sanding. In instances of more severe rot it was impractical to prepare the cross-sections using wood glue. The inefficient use of time, and glue, would hinder research progress. Associated issues include the premature wear of sanding belts, which become clogged with glue.

Krusic and Hornbeck (1989) outline an advanced method of saturating extremely rotted wood with wood glue that is still being utilized today (Kulha et al 2018). They do not specifically report the amount of time required to prepare a sample using their method, they do write that saturation "...was generally completed within 48 hours" (Krusic and Hornbeck 1989:24), with larger samples taking up to two weeks. Their method, while successful, requires the use of specialized equipment, and a significant amount of time.

A specialized method for treating the Moose Horn Pass fence system cross-section was developed to quickly prepare the disks in a way that did not require the use of specialized equipment, or material. The new method does not lead to the premature wear of any processing equipment or material.

Drawing on familiarity with products used during previous construction experience, I proposed that by applying two specific products, the cross-sections could be strengthened and processed quickly and efficiently. Cross-sections exhibiting rot and material loss were first wrapped several times with duct tape. They were then treated with 3M™ spray adhesive to bind loose wood fibres, and any larger pieces of material that appeared likely to separate. The adhesive dries relatively quickly (~15 minutes), which allows for additional applications within hours if required. The next step required the filling of voids using Great Stuff™ Window & Door Insulating Foam Sealant. This particular product is designed for window and door installations where high expansion foam would distort frames and prevent proper operation. The foam expands without changing the physical dimensions of the material surrounding the void. The product is engineered to be cut and sanded, and is generally dry within ~60 minutes. Rotted cross-sections were treated and ready for cutting and sanding within 90-120 minutes.

Using this method, 11 of 12 treated archaeological cross-sections yielded end dates, with seven of those included in their entirety within the site's final master chronology. The inclusion of the rotted cross-sections was especially important during the earliest years of the master chronology, where they represented up to 23% of the total number of series' present (Figure A. 1).

This inexpensive, easy, and quick method of cross-section repair can be utilized in any dendrochronological research, preserving the ring record of disks that might otherwise yield fewer rings than they are capable, or be discarded altogether.

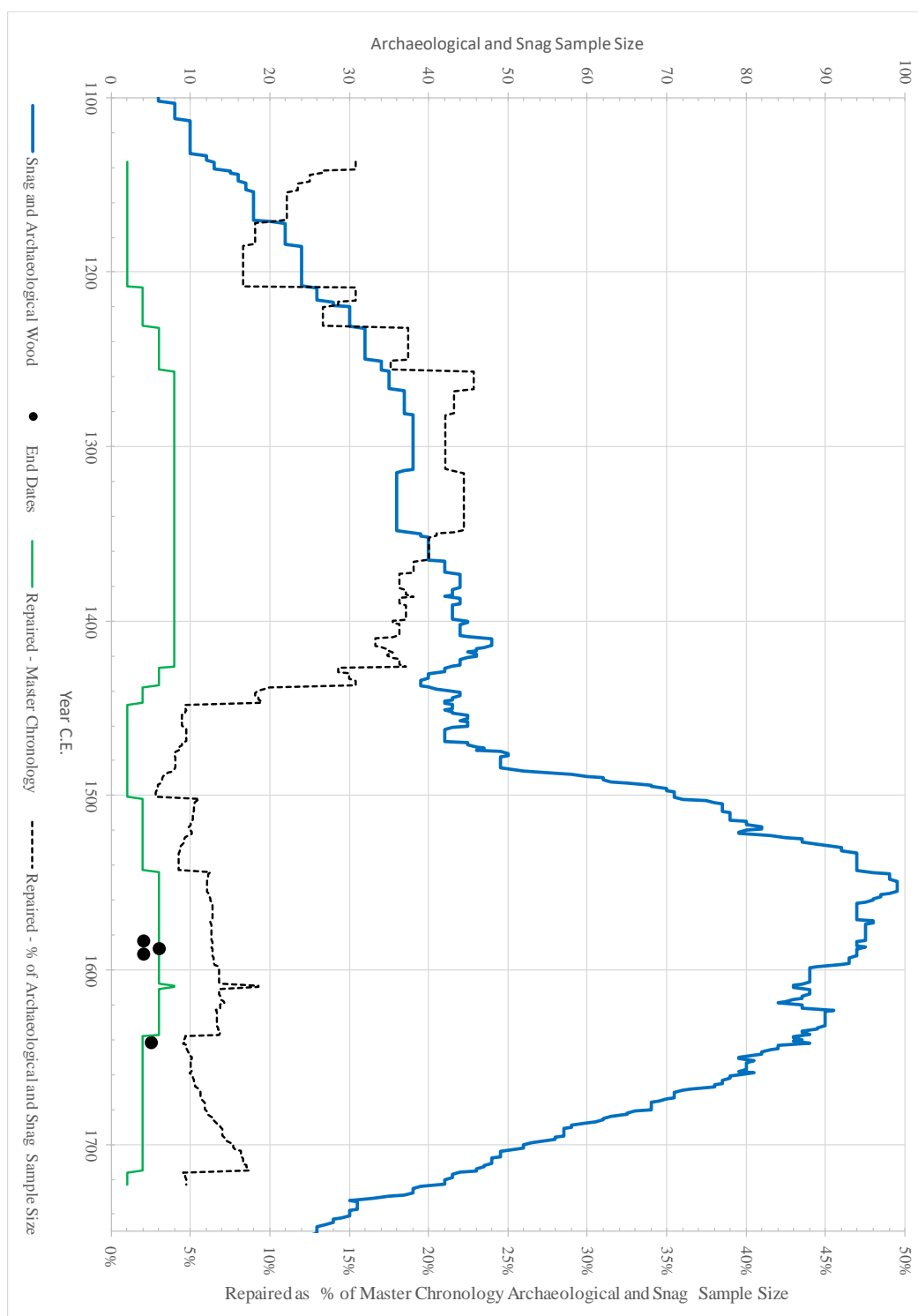


Figure A. 1 - Repaired cross-sections in master chronology. Total quantity, and as a percentage of total combined archaeological and snag sample size.

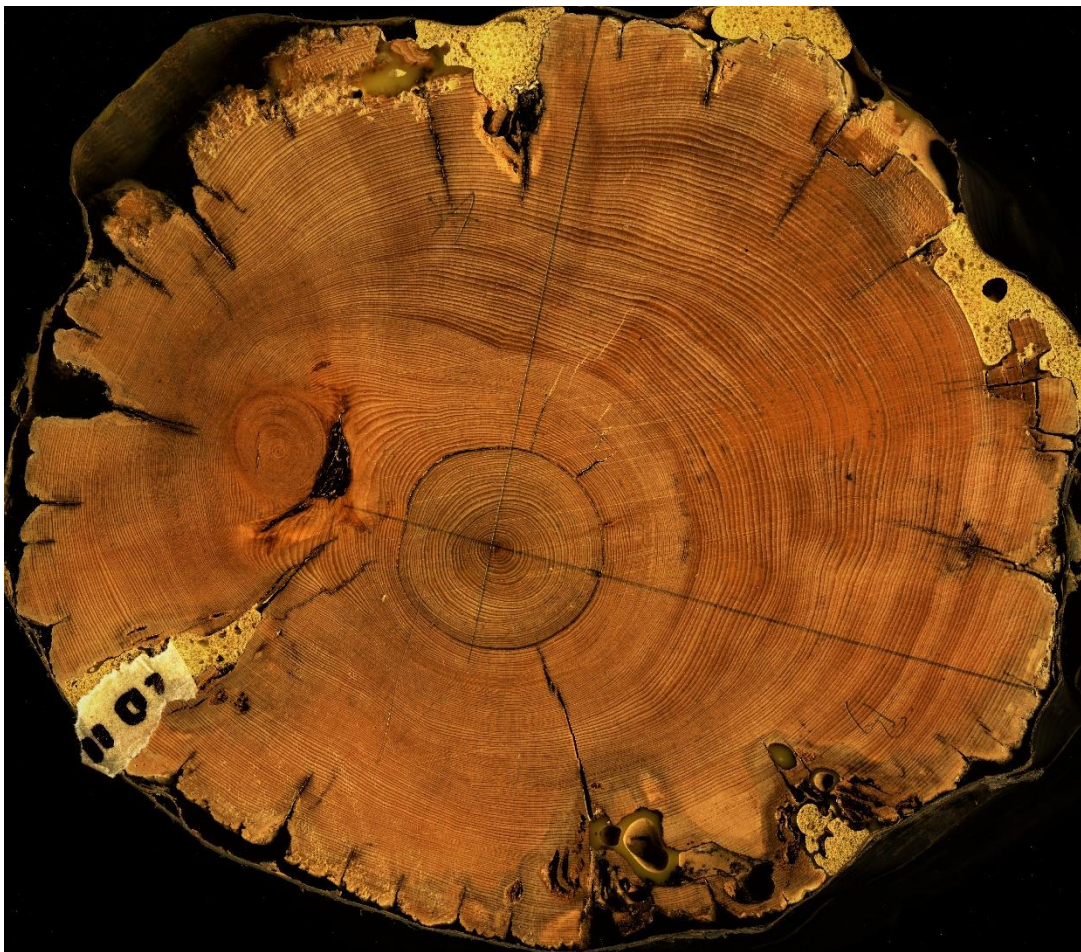


Figure A. 2 - 16LD011; 1232-1426



Figure A. 3 - 16LD028; 1588 END DATE



Figure A. 4 - 16LD029; 1642 END DATE

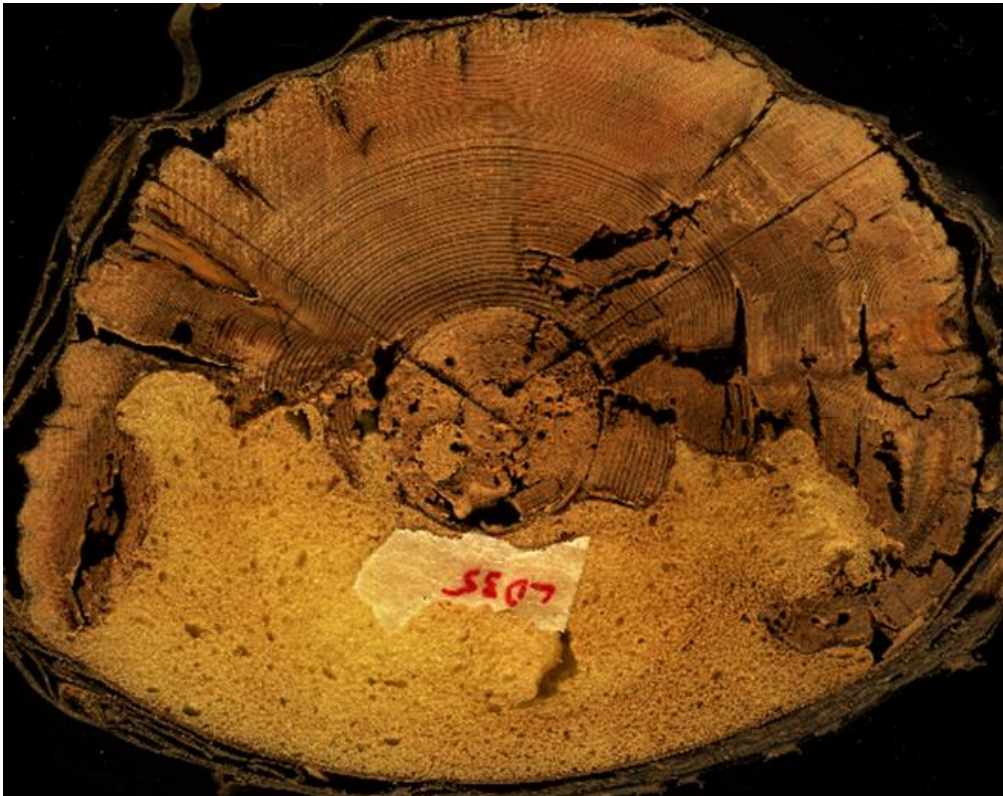


Figure A. 5 - 16LD035; 1609-1723



Figure A. 6 - 16LD040; 1257-1637

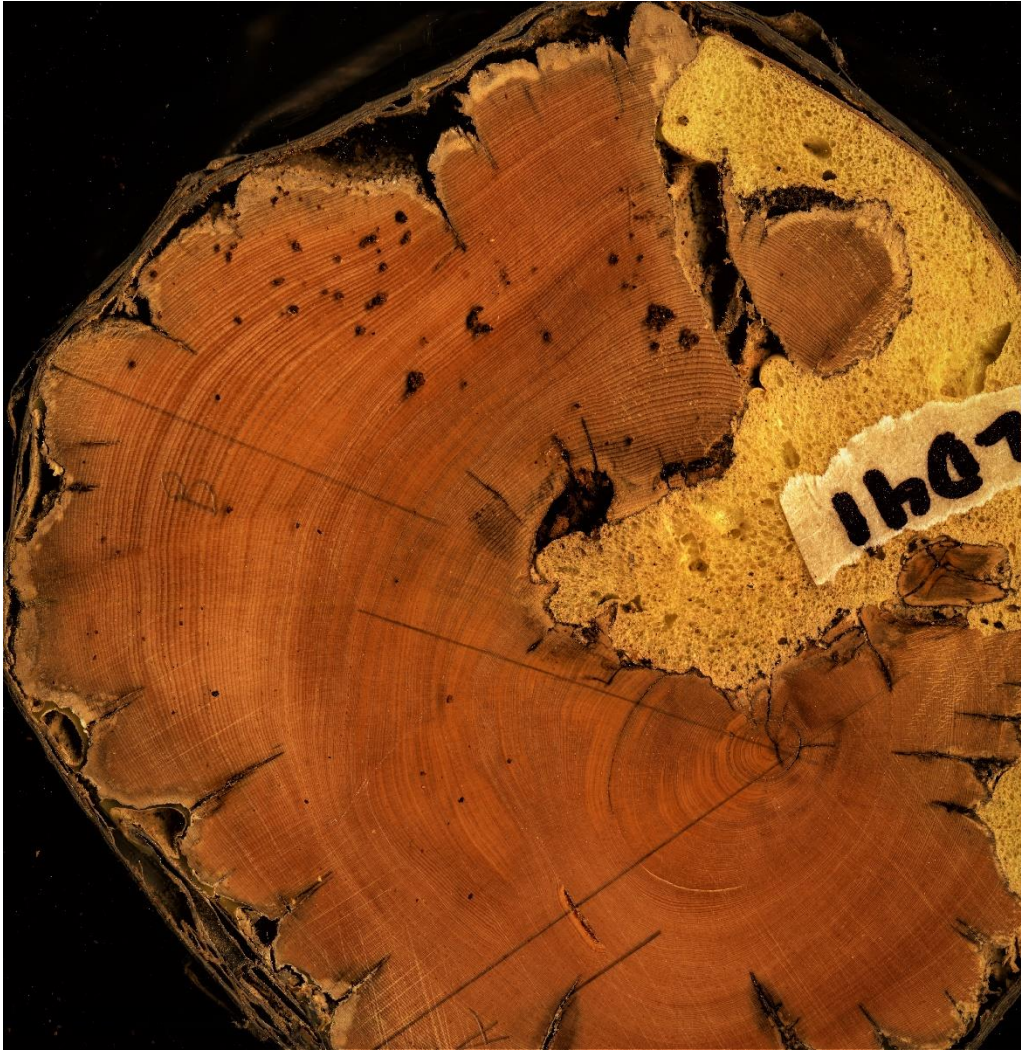


Figure A. 7 - 16LD041; 1137-1447

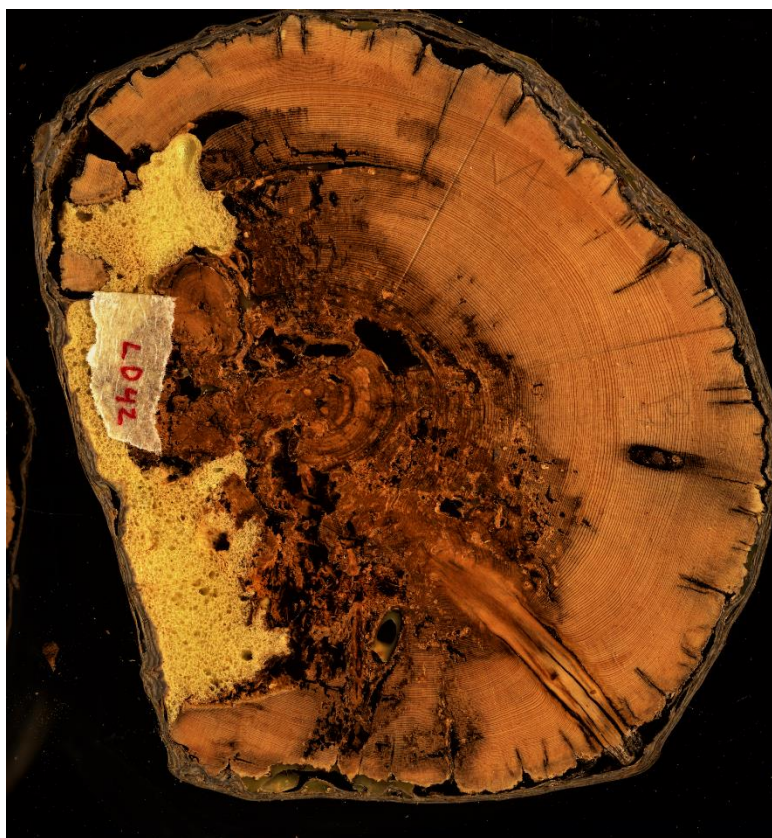


Figure A. 8 - 16LD042; 1544-1715



Figure A. 9 - 16LD043; 1591 END DATE



Figure A. 10 - 16LD060; 1209-1437



Figure A. 11 - 16LD062; 1502-1610



Figure A. 12 - 16LD064; 1584 END DATE

Appendix B: Calculations

NDVI

$$\text{NDVI} = (\text{NIR} - \text{RED}) / (\text{NIR} + \text{RED})$$

GNDVI

$$\text{GNDVI} = (\text{NIR} - \text{GREEN}) / (\text{NIR} + \text{GREEN})$$

CORRECTED AVERAGE

$$((\text{SUM OF END DATES IN SERIES}) - (\text{MAXIMUM YEAR IN SERIES} + \text{MINIMUM YEAR IN SERIES})) / (\text{NUMBER OF END DATES IN SERIES} - 2)$$

Appendix C: Referenced Figures



Figure C. 1 - Photograph of Phantom IV UAV and Parrot Sequoia multi-spectral sensor array.



Figure C. 2 - Photograph of UAV and operator in the field.



Figure C. 3 - Photograph of 5.1mm increment borer.



Figure C. 5 - Cores mounted on boards.

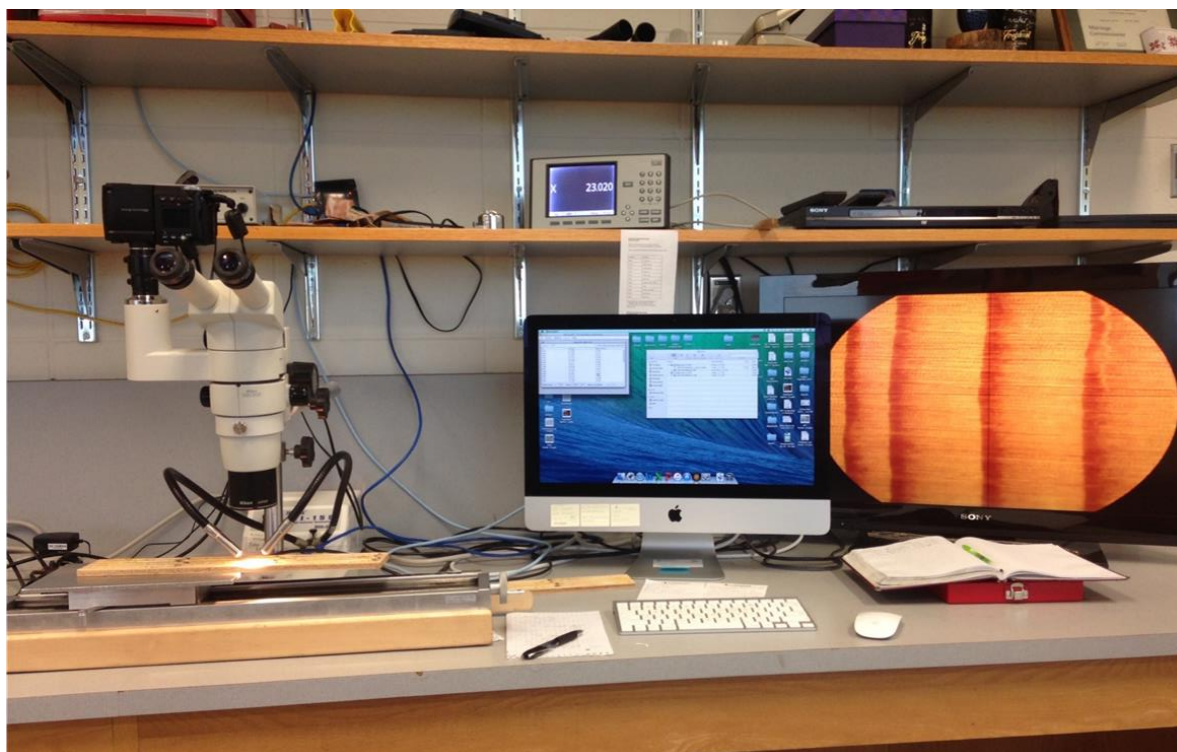


Figure C. 4 - Velmex Stage System.



Figure C. 6 - Fence line, overlapping timbers.

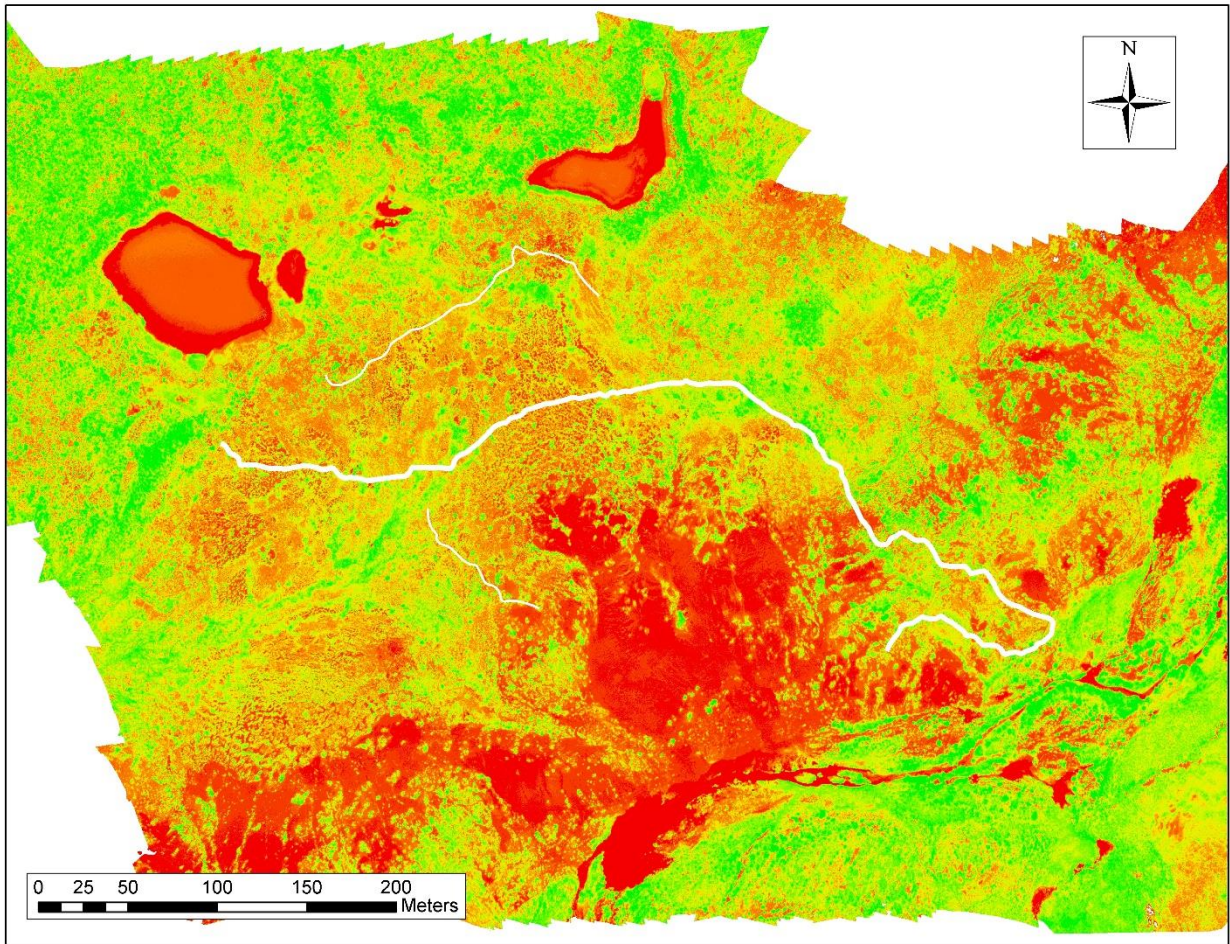


Figure C. 7 - NDVI visual.

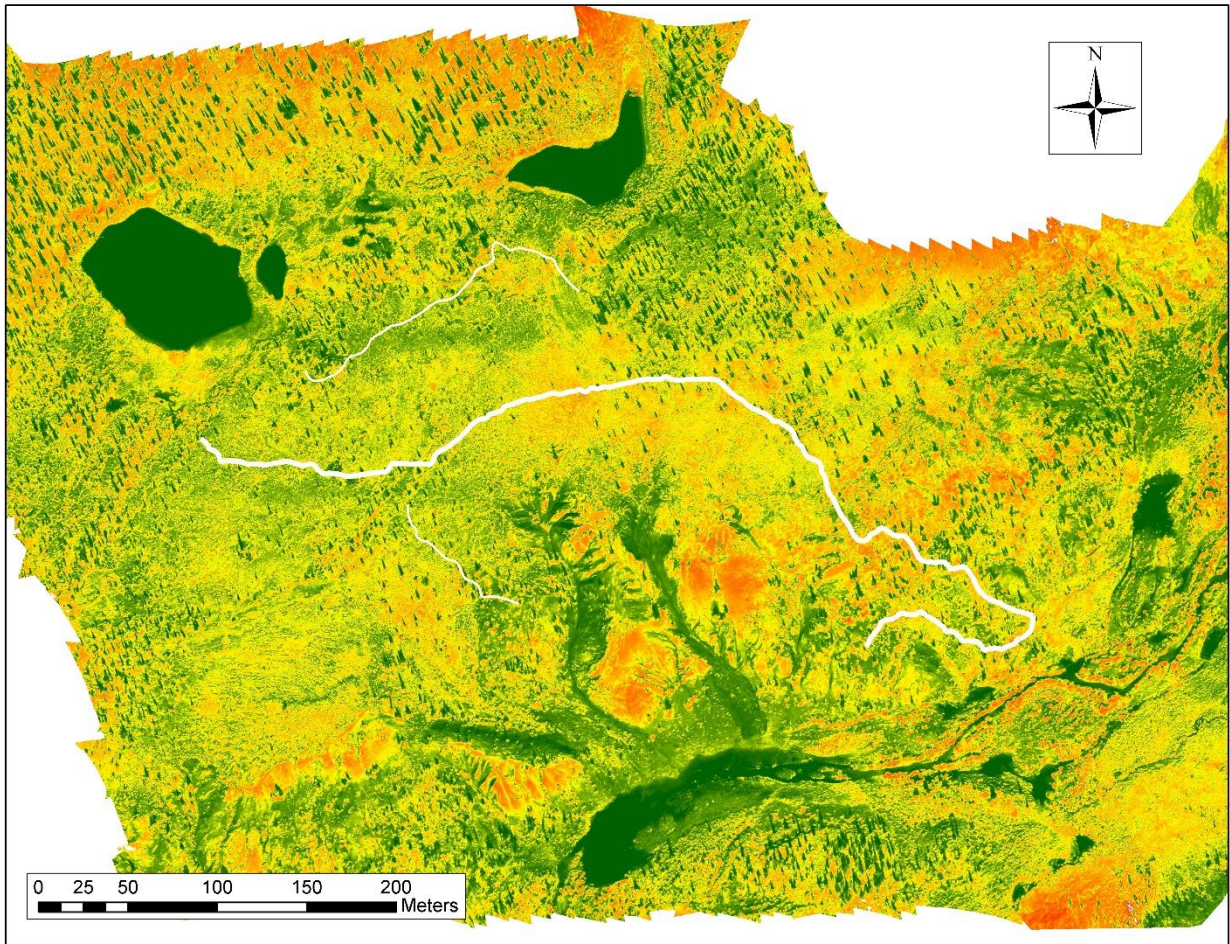


Figure C. 8 - NIR visual.

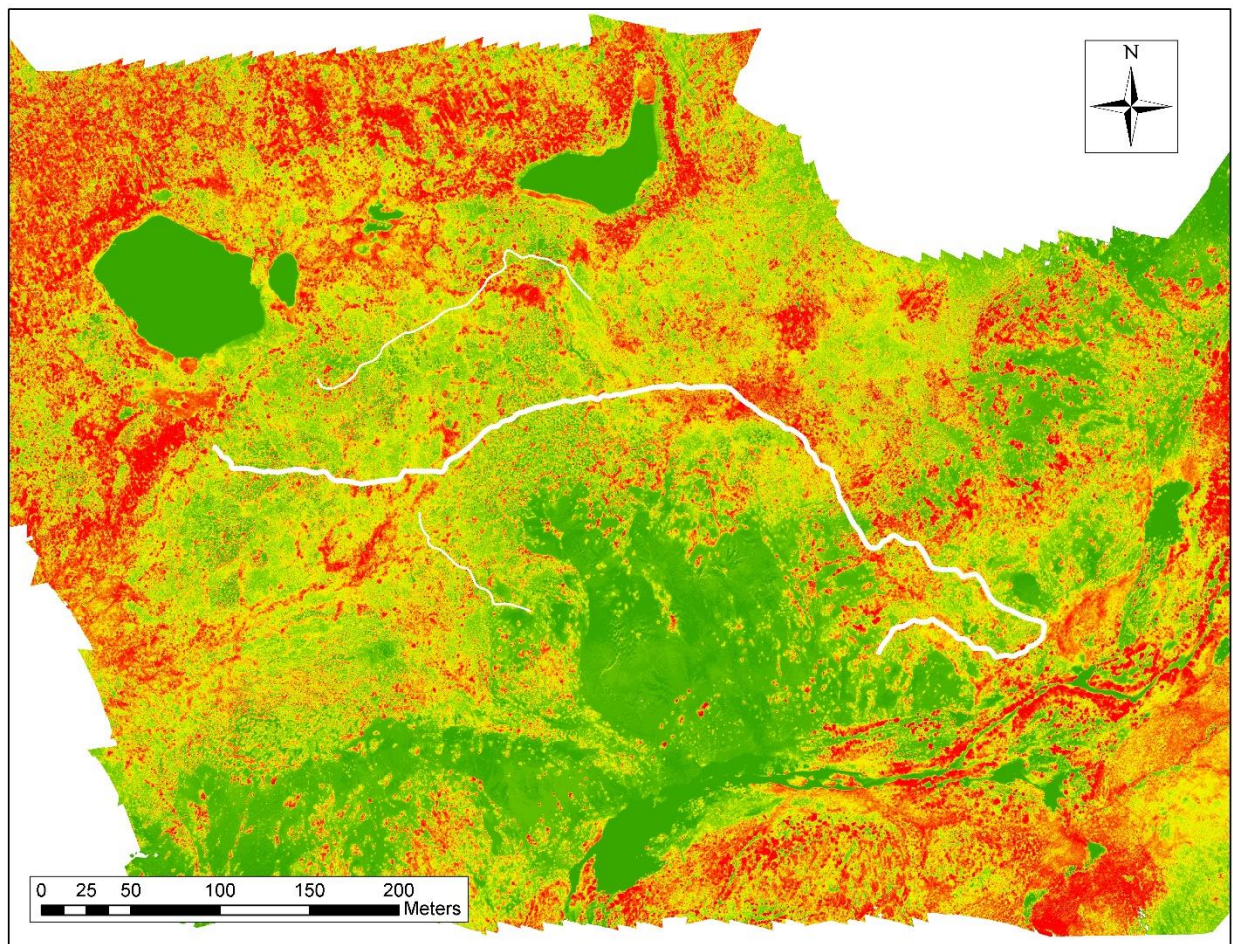


Figure C. 9 - GNDVI visual.

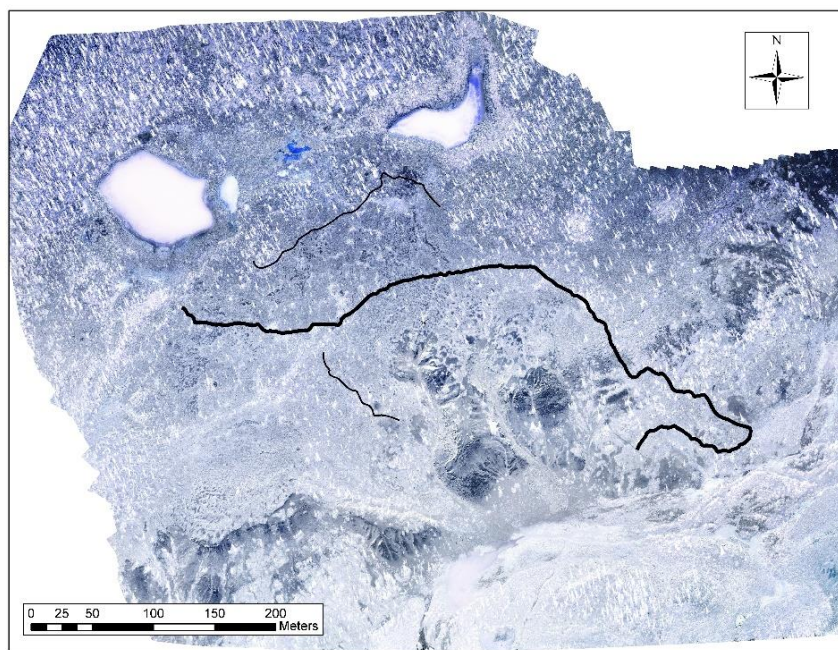
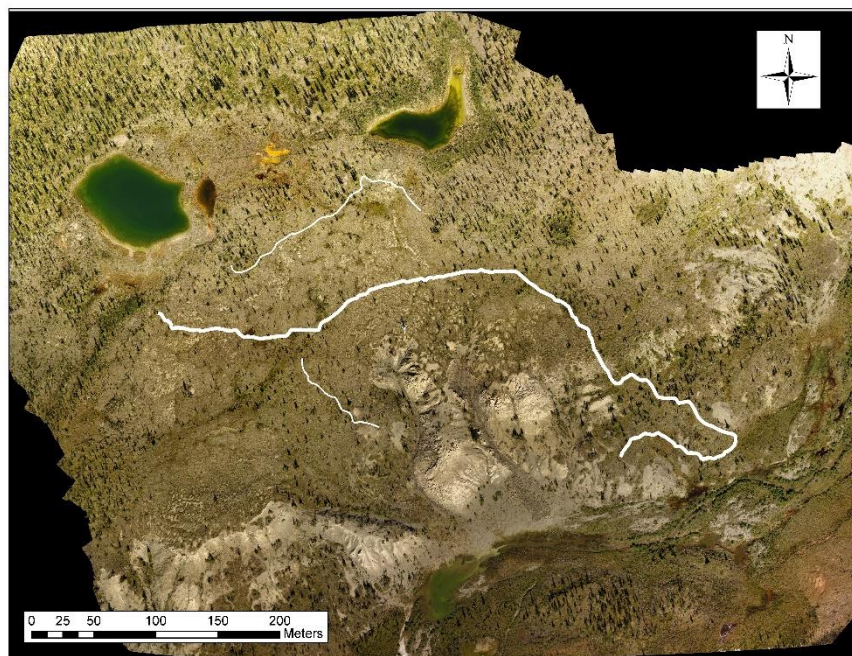


Figure C. 10 - RGB and Modified RGB.



Figure C. 11 - Valley slope vegetation (Salix sp.).

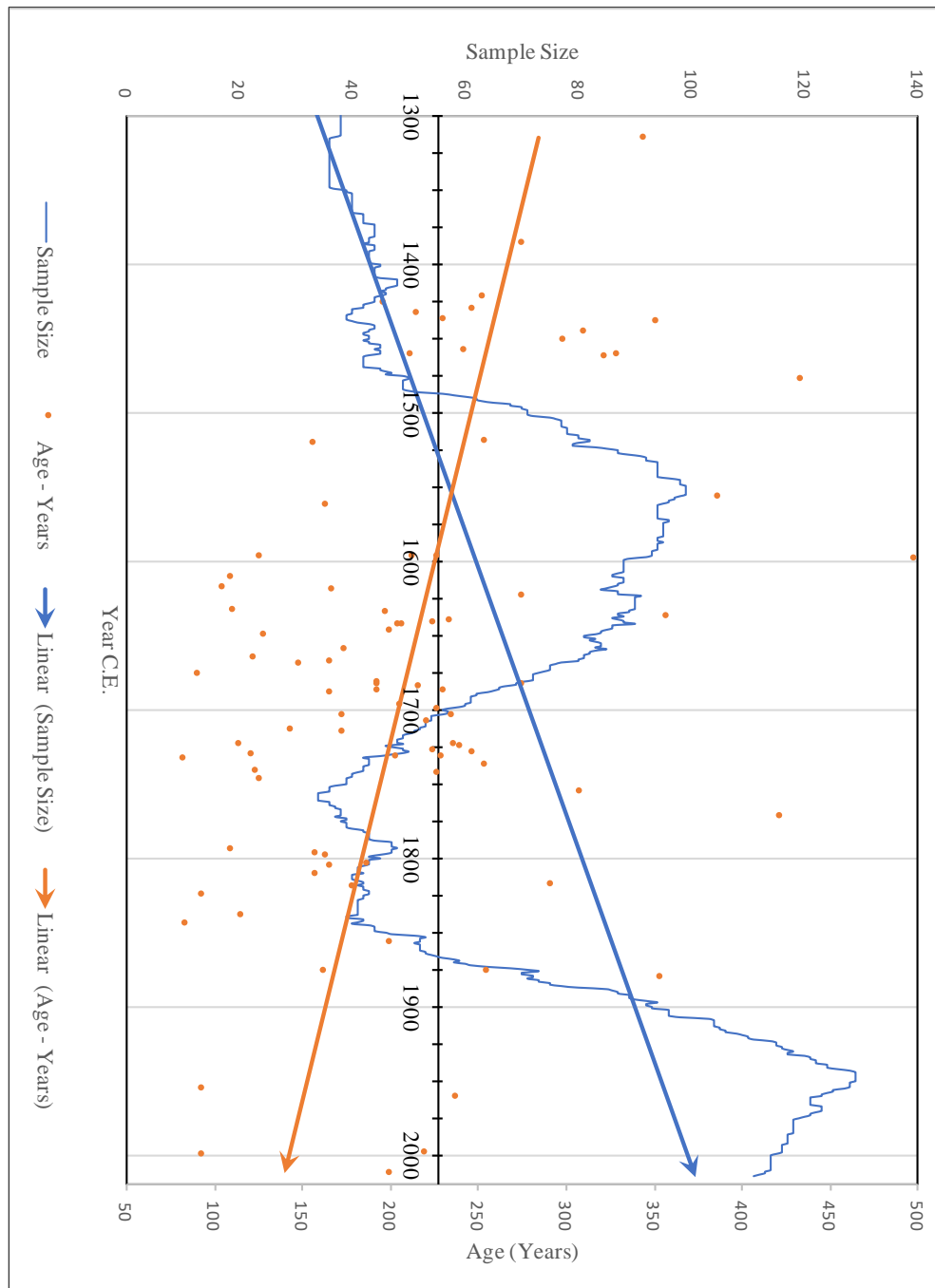


Figure C. 12 - Decrease in Tree age/sample size increase from past to current.

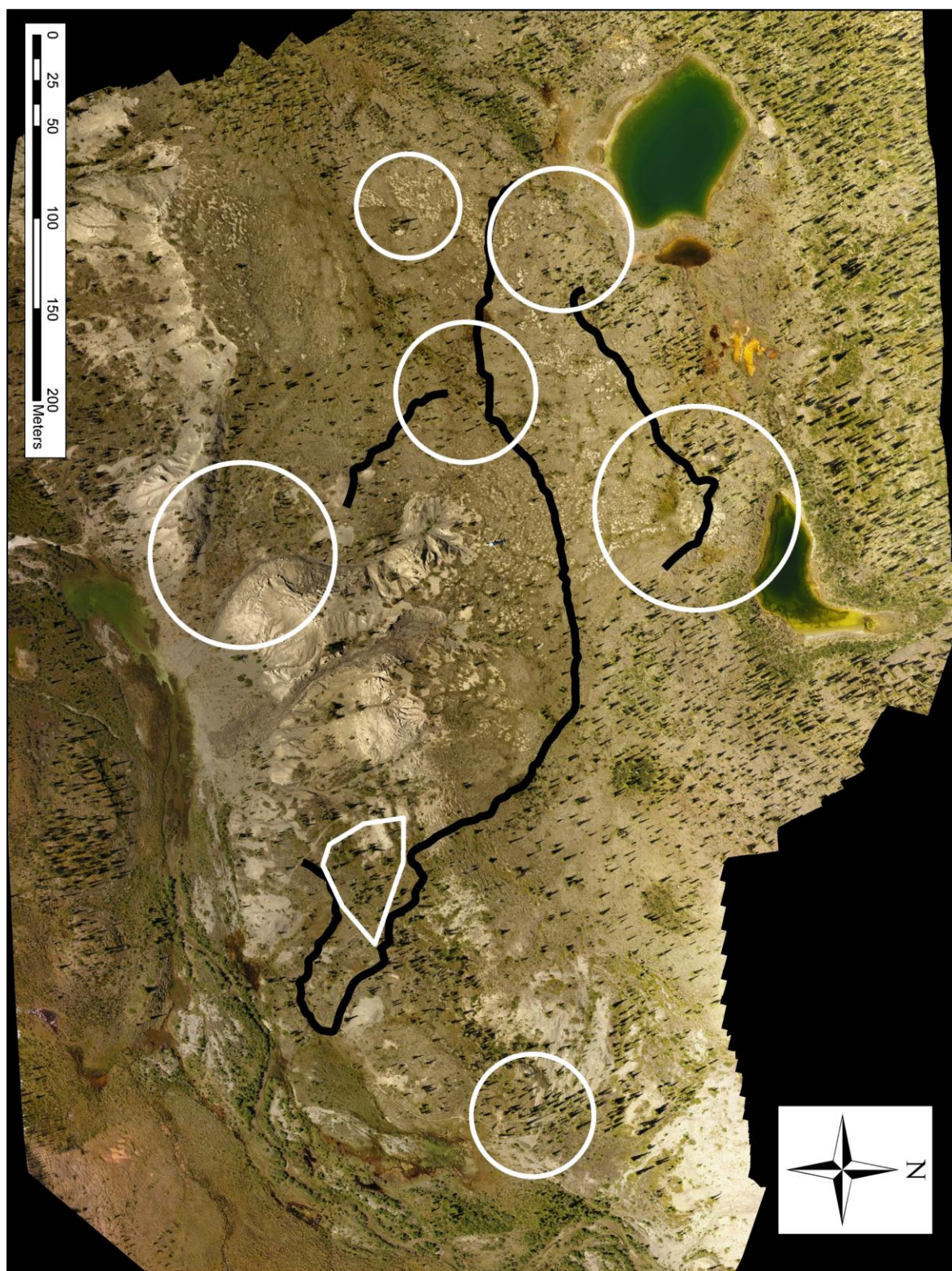


Figure C. 13 - Areas suggested to have high archaeological potential.

Appendix D: Referenced Tables

Years	Individuals	# of Series	Segments 50/25	Total Rings	Correlation (Pearson)	Flags	% of Segments with Flags	Flagged Segments “Highest as Dated	Flagged Segments $\leq .05$ difference between “Dated” and Highest Possible	Number of remaining segments >.3281	Flagged Segments Remaining
1045	160	317	2146	54326	0.562	116	5.4	51	35	5	25

Table D. 1 - Breakdown of COFECHA flags.

	NORTH		EAST		PLATEAU		VALLEY		WASHOUT	
	FYOG	AGE	FYOG	AGE	FYOG	AGE	FYOG	AGE	FYOG	AGE
AVERAGE	1805	210	1847	169	1899	117	1873	143	1855	161
MEDIAN	1821	195	1886	130	1892	124	1874	142	1886	131
MAXIMUM	1888	376	1944	375	1967	219	1939	243	1923	290
MINIMUM	1639	127	1641	72	1797	49	1773	77	1726	93
ADJ. AVG.	1810	205	1857	159	1901	115	1875	141	1886	131
*Adjusted Average (ADJ. AVG.) excludes maximum and minimum values from calculations.										

Table D. 2 - Average ages of trees from each coring zone.

MARKER YEARS					
YEAR	LIMIT	FROST	YEAR	LIMIT	FROST
1185	X	X	1721		X
1205	X	X	1752	X	
1244		X	1769	X	
1300		X	1773	X	
1320	X		1783	X	
1467	X		1799		X
1473	X	X	1803	X	
1504		X	1804	X	
1507	X		1805	X	
1519	X	X	1817	X	
1520	X		1819	X	
1550	X	X	*1850	X	
1598	X		1877	X	
1623		X	1898		X
1648		X	1904	X	
1710	X		1973	X	
*Two ring sequence: narrow 1850/wide 1851					

Table D. 3 - Key Ubiquitous Marker Years.

Appendix E: Additional Figures



Figure E. 1 - PWNHC caribou fence exhibit.



Figure E. 2 – 2016 field crew: (l-r) Dr.Colin Laroque, Dr.Tom Andrews, Gary Beckhusen, Jurjen van der Sluijs, and Glen MacKay.



Figure E. 2 - (l-r) Leon Andrew, Gary Beckhusen, and Lukas Smith.